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The Cambridge Subway

By L. E. Moore*

The Cambridge Subway, soon to be opened to traffic, is one of the links used by the Boston Elevated Ry. Co. in its development of rapid-transit facilities between the central part of the city of Boston and its outer portions and suburbs.

In order to explain its relation to the other parts of the system, it will be convenient to describe briefly the transit situation as it now exists. Boston may be likened to the hub of a wheel and the channels of traffic to its various suburbs to the spokes. It is necessary to provide transit facilities from Boston to all these suburban towns. The steam railroads provide for transit to the more distant of the suburbs, but the traffic within the radius of a five-cent fare naturally gravitates to the street-railway companies. Not to go too closely into detail, it must suffice to say that, placing the hub of the wheel in the business district, the spokes of the wheel must cover more than three-fourths of a full circle in order to take in all the surrounding territory which it is necessary to reach. The map, Fig. 1, shows the inner portion of this territory, with the existing surface lines and the existing and proposed elevated and subway lines.

A little consideration will show the practical impossibility of providing subways or elevated railways to reach each of these points separately, as the traffic along each spoke of the wheel would not be sufficient to pay for the cost of construction and maintenance of the line. Moreover, it is not practicable to collect the surface cars at certain points and run them into the city on an elevated structure or through a subway, on account of the many tracks which would be required to handle such a traffic without undue congestion, and also on account of the expense involved in handling a large traffic in small units. The solution arrived at, then, has been, so far as practicable, to collect the surface cars at certain focusing points and there transfer passengers to elevated or subway trains, run in comparatively large units and capable of operating with a maximum of speed and a minimum of obstruction to traffic. These focusing points are not confined to the ends of the elevated or subway systems, but are to a greater or less degree located at various stations along the main trunk lines.

Generally speaking, the plan as it is now being developed provides for two intersecting through trunk lines, which shall pass through the central portion of the city approximately at right angles

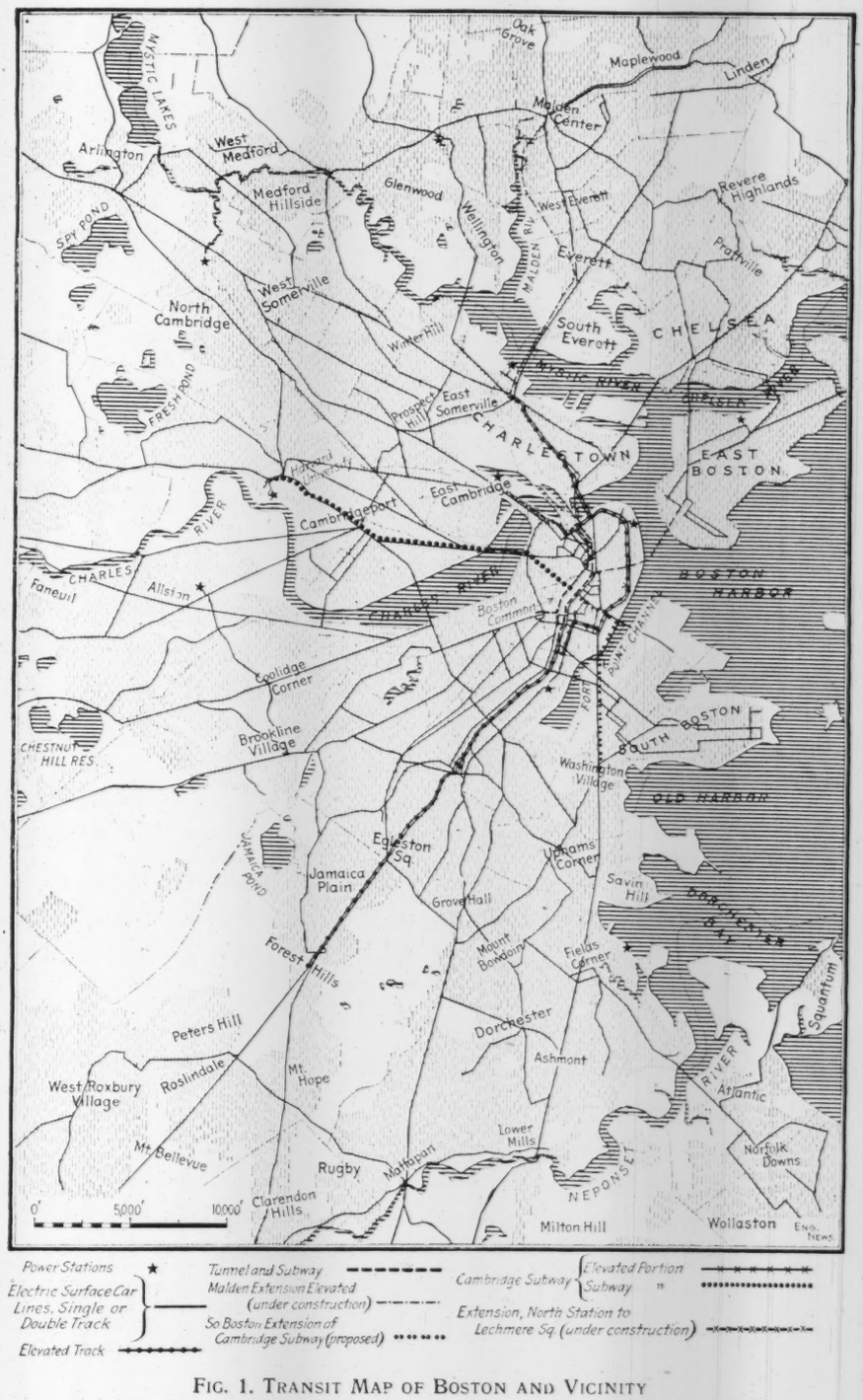

Fig. 1. Transit Map of Boston and Vicinity

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to each other. The map, Fig. 1, shows both the completed and projected portions of these lines. The function of these lines is to collect the passengers from surface cars at outlying points and distribute them to various stations in the business portion of the city.

Of these trunk lines, one has been built and in use for some years. This is the line from Sullivan Square in Charlestown to Dudley St. in Roxbury. This line has recently been extended to Forest Hills on the south, and is now being extended to Malden on the north (Fig. 1). It is elevated for all of its length, except for about 1½ mi. in the city of Boston, where it runs in what is known as the Washington Street Tunnel. It includes a loop elevated line around the water front, following Atlantic Ave. and passing the South Terminal Railroad Station. Part of the trains are run via this loop, but the majority are run through the tunnel.

The Cambridge Subway is a part of the other trunk line, and will be the first portion of this line to be put in operation. Except for a portion of its length, extending across the Cambridge Bridge and continuing for a short distance in Boston until it reaches Beacon Hill, the line is entirely underground. When completed, trains will be operated between the Park Street Station in Boston and Harvard Square in Cambridge. Fig. 2 is a diagram showing that portion of Fig. 1 which includes the Cambridge Subway. The present intention is to ultimately continue this line, beyond Park Street Station down Winter and Summer Sts., crossing under the Washington Street Tunnel, and then past the South Terminal Station and under Fort Point Channel to a point in South Boston in the vicinity of Andrew Square (see Fig. 1). The present Boston terminus is at Park St., which is the busiest station on the old Tremont Street Subway. This latter is now altogether used by surface cars.

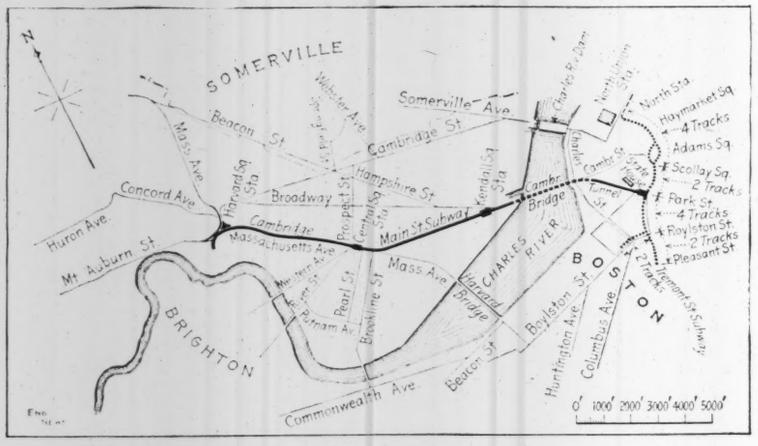


FIG. 2. SKETCH MAP OF CAMBRIDGE SUBWAY AND CONNECTIONS

TREMONT STREET SUBWAY—The Tremont Street Subway was the first one built in the United States; it was entirely completed in 1898. It was constructed primarily to relieve the great congestion of surface cars on Tremont St. The maps Figs. 1 and 2, show its location. Plans are now being made for the extension of this subway out Boylston St., and probably Beacon St. to the junction of Commonwealth Ave. and Beacon St. This subway is to be used by surface cars only, partly because the grades and curves of the old portion are not suited to the operation of trains, although for some time part of it was used by the elevated trains while the Washington Street Tunnel was being constructed.

It should be explained, in order to give a better idea of the whole situation, that there are two tracks in the Tremont Street Subway extending continuously through from the North Station to Pleasant St., two other tracks extending from the North Station to a loop under Scollay Square, and two others extending from the Public Garden to a loop at Park St. (see Fig. 2). The situation is complicated by the fact that the Bay State Street Ry., an independent corporation, provides the majority of the traffic from the North Station to the loop under Scollay Square.

EAST CAMBRIDGE ELEVATED—Another elevated structure, designed for use of surface cars and intended to facilitate their progress through certain congested streets, is also being erected at the present time in the vicinity of the North Union Station. It involves an elevated structure, including a concrete arch bridge over the Charles River just below the Charles River Dam, and extends from the North Station to an incline in Lechmere Square in East Cambridge.

LOCATION AND DESIGN OF CAMBRIDGE SUBWAY

To return to the Cambridge Subway, it extends from a new station at Park St., constructed directly beneath and generally at right angles to the present Park Street Station of the Tremont Street Subway, by a tunnel under Beacon Hill to a point on private land at the corner of Phillips and Grove Sts., where it emerges and continues on private land on an elevated structure to the corner of Charles and Cambridge Sts., and then across the Charles River on the Cambridge Bridge. At the Cambridge end of this bridge it descends into the Cambridge Subway proper, remaining underground for the rest of the distance to the Harvard Square Station, which is also completely underground. The total length from Park St. to Harvard Square is 17,000 ft., and from the Cambridge Bridge to Harvard Square is 11,700 ft.

The underground portion in the city of Boston, including the new Park Street Station, was constructed by the Boston Transit Commission. The elevated portion in the city of Boston and the whole of the work in Cambridge was done by the Boston Elevated Ry. Co. When the Cambridge Bridge was built (1907) a space was left in its center in preparation for the construction of this line.

The running time between Park St. and Harvard Square by the new subway will be 8 mins. The present running time between these points (surface cars) is 23 mins.

From the Cambridge Bridge to a few hundred feet beyond Central Square the subway was built in open cut; from that point to beyond Putnam Square it was built by a shield under atmospheric pressure, and the remainder was built in open cut.

Fig. 3 shows at the left a clearance diagram for the Cambridge Subway, defining the minimum allowable interior section on tangents. On curves, the section was enlarged to give a standard clearance of 12 ins. at the eaves of the car and 18 ins. from the top of rail to a point 9 ft. above. The car was assumed to be 70 ft. long, 10 ft. wide, 46 ft. 7¼ ins. center to center of trucks, and 10 ft. 4 ins. high from top of rail to eaves. The proper allowance was made for tilting of car due to superelevation of outer rail. This superelevation was limited to 6 ins.

Typical cross-sections are also shown in Fig. 3. Wherever possible, the roof was arched, but at certain points the depth of cover was so small that it was necessary to use a flat roof. The reinforcement in either case was varied to suit the different depths. At points of shallow cover, the flat roof section was built with Bethlehem steel beams, covered, of course, with concrete. The thicknesses of walls and roof were varied to meet local conditions of depth of cover, interior width, and elevation of groundwater. The minimum thickness of invert used was 19 ins. The section adopted

for the tunnel portion (Fig. 3) gives an inside width of 26 ft. 10 ins., while the part built in open cut is 25 ft. wide. The reason for this is that the shield had to be built large enough to give proper clearance for cars on curves in the finished tunnel, so that the tangent sections could not be reduced to standard size, as was possible in the open-cut work.

Construction Methods

Open-cut—The method of building the subway in open cut was to excavate a 40-ft. section to the bottom for the entire width of the subway. The spoil from this excavation was handled by means of derricks and cable ways. Five electric derricks and three cableways in all were used, being shifted from place to place as the work progressed. The sides of this trench were protected by two rows of 2-in. sheeting, driven as the excavation proceeded. When the bottom was reached in one of these sections, a 4-in. mat of concrete was laid, upon which the waterproofing was placed. The waterproofing used was four-ply heavy tarred felt, each layer being mopped with tar as it was placed. The invert of the subway was built on this waterproofing and the side walls were then carried up on both sides for the entire length of the section. This work was done in three stages, to allow for the removal of the rangers and braces. The forms for the roof were then built, the reinforcement placed, and the concrete put in. On the lower half of the sides the waterproofing was placed against the sheeting, as the latter was left in place below groundwater. The waterproofing for the upper half of the wall and for the roof is continuous and covered by a protective coat of 3 ins. of concrete.

Tunnel—The detailed method of constructing the tunnel was as follows:

Two drift tunnels, 9 ft. high and 8 ft. wide, were excavated on the sidewall lines. These drifts were continuously timbered on the tops and sides nearer the center of the tunnel with 6 × 8 hard-pine caps and legs. The outside legs were 8 × 2½-in. reinforced-concrete boards. The timber portions were removed when the core was excavated and were used repeatedly, but the concrete boards were left in place. The sidewalls were built in the drifts in 16 and 20-ft. lengths, to a height of 4 ft. 4 ins. above the rail. These walls supported and guided the roof shield.

The shield, weighing about 70 tons, traveled on eight steel rollers on each wall. It was propelled by fourteen 125-ton hydraulic jacks attached to the shell at points about equidistant from each other. These jacks reacted on cast-iron push-rods embedded in the completed arch behind the shield.

The push-rods were cross-shaped in section except for a length of 1½ ins. at each end, which was of circular cross-section about 3 5/16 ins. in diameter. One end of the rod was convex and the other concave in order that successive lengths might be properly placed and retained in contact. The object of the rods was to carry the reaction of the jacks through the green concrete to that which had set firmly. This arrangement obviated the necessity of waiting until the ring immediately behind the shield had set before advancing the shield. The rods were left in place in the completed concrete and form continuous lines through it.

The jacks were supplied by two duplex double-acting electrically driven pumps which could furnish water at a pressure of either 1,500 or 5,000 lbs. per sq.in. The higher pressure was intended to be used only in case the ground was so soft that the shield had to be pushed directly into it without excavating in advance; it was never necessary to do this.

The concrete arch was constructed in 30-in. sections under the tail of the shield at the same time that 30 ins. in length of earth core was being excavated in front of the shield the full width of the tunnel. The ground was so hard that this length stood unsupported in all cases. The centering for the arch was made of steel ribs 30 ins. apart, with beveled lagging 3 ins. thick. This lagging was laid on the ribs just in advance of the concrete while the latter was being placed up around the arch. A sectional wooden bulkhead was put on the lagging to prevent the concrete from falling into the shield. The steel ribs were left in place for 2½ weeks and were then removed and used again.

Grout was forced into spaces left between the outside of the concrete arch and the surrounding earth by the passage of the shell of the shield. This was done by means of a Caniff grout mixer operated by compressed air at 80 lbs. pressure.

The tunnel portion is not waterproofed, but after its completion grout was forced out through pipes wherever leaks showed.

The ground encountered for the most part was sand and gravel cemented with a small amount of clay and was of a very firm consistency. At some places the

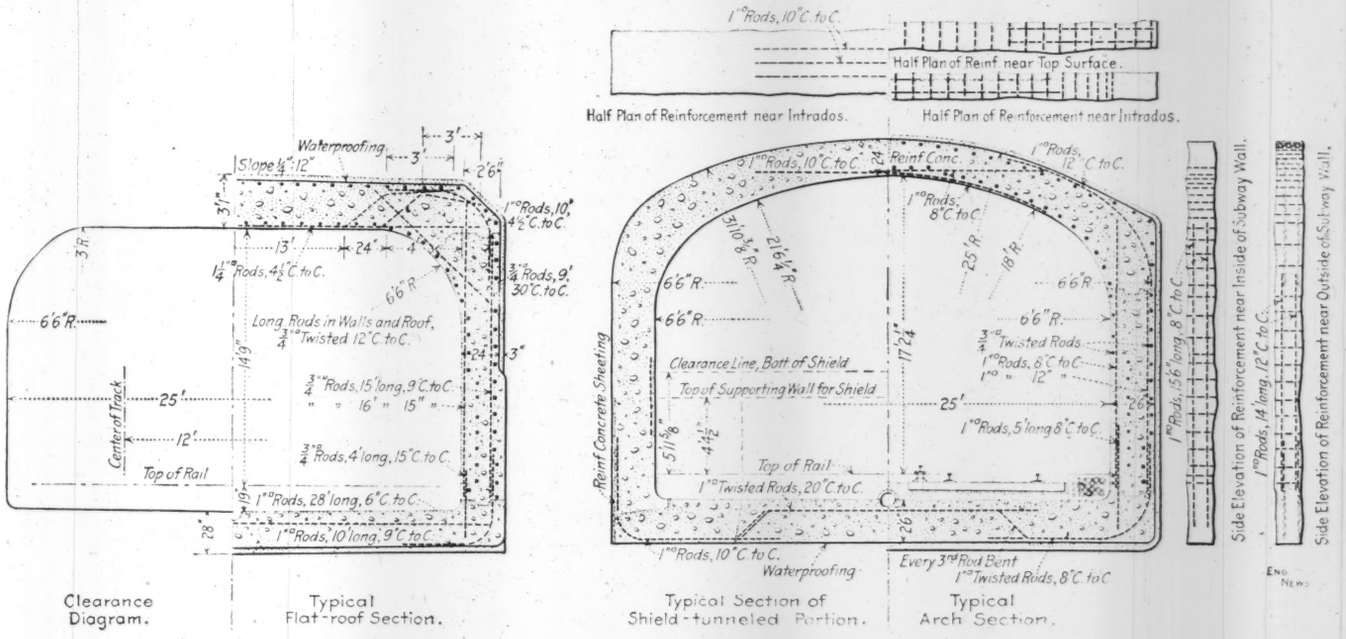

Clearance Diagram.
Typical Flat-roof Section.
Typical Section of Shield-tunneled Portion.
Typical Arch Section.
Waterproofing
Long Rods in Walls and Roof, ¾" Twisted 12" C. to C.
Clearance Line, Bott. of Shield
Top of Supporting Wall for Shield
Top of Rail
Reinf. Concrete Sheeting
Half Plan of Reinf. near Top Surface.
Half Plan of Reinforcement near Intrados.
Side Elevation of Reinforcement near Inside of Subway Wall.
Side Elevation of Reinforcement near Outside of Subway Wall.

Fig. 3. Typical Sections of Cambridge Main St. Part of Cambridge Subway

sand and gravel had none of the clay cementing material. The tunnel spoil and material was handled through a shaft located on private land at the corner of Bay St. and Massachusetts Ave. The spoil was conveyed in small cars holding about 1 cu.yd. over a trestle from this shaft to a series of hoppers located on private land at a convenient distance from the shaft. The material was discharged from the hoppers into teams which carried it away.

The concrete for use in the tunnel was mixed in a "Municipal" concrete mixer placed in the shaft, underneath bins for the materials, the latter being filled from teams dumping through hatches in the shaft top at the street surface.

SUPPLY OF MATERIALS—The greater part of the material used was received in a central storage yard located on the Grand Junction branch of the Boston & Albany between Massachusetts Ave. and Main St. The stone arriving in the cars was put into teams or bins by a clam-shell unloader. A concrete mixer fed from the bins mixed the concrete for the open cut work. This concrete was hauled in wagons to the place on Main St. where it was used. Some cement and lumber was received at Somerville on the line of the Boston & Maine, which is nearer to Harvard Square than the Main St. store yard was.

AUXILIARY WORK—There were, of course, the usual changes to make in conduits, gas and water mains and sewers. In addition the track of the Grand Junction branch of the Boston & Albany had to be supported where it crossed the subway. This portion has a flat roof heavily reinforced with 24-in. I-beams, and is a sufficient distance below the surface to allow the railroad tracks to be dropped 8 ft. in the event of future grade-crossing abolition.

STATIONS

HARVARD SQUARE TERMINAL — The Harvard Square Station, located at the western terminus, merits careful study. It consists essentially of an underground two-level fan-shaped station (see Fig. 5). There are separate platforms for loading and unloading all cars and trains, and the passageways to and from these platforms are so arranged that traffic takes place through them in only one direction. It is possible thus to provide for bodily transfer of passengers without the use of any check, or the placing of any obstructions such as turnstiles or gates in the passageways. The surface cars from the general direction of Arlington (see Fig. 4 for surface trackage) arrive on the lower level and unload passengers desiring to go to Boston; then they proceed to another platform, receive passengers coming from Boston via the subway, and finally proceed to Mt. Auburn. Surface cars arriving from the general direction of Mt. Auburn go through a similar process on the upper level and then proceed to Arlington. In order to accomplish this the surface cars descend an incline on a 5% gradient at either end to reach the level of the subway (Fig. 4), and after loading climb out of the subway to the surface on another similar incline.

The subway trains arriving from Boston unload on one level, their passengers alighting and taking a passageway to either the upper or lower level according to whether they wish to go to Arlington or Mt. Auburn. The train is then either run through to the Eliot Square carhouse or switched to the loading platform for Boston. In the latter case it loads with passengers who have arrived from Mt. Auburn or Arlington on the upper or lower level surface car platforms.

There are no stairways except for passengers who wish to go to or enter from Harvard Square, that is who do not wish to transfer between the subway and surface cars.

The actual construction of this station with its various inclined passageways was quite a complicated piece of work, but by adopting this method the passengers always move in only one direction in any one of the four main passageways. Although the arrangement seems rather complicated, it is really extremely simple for the individual passenger. If he comes from Boston, he alights from his subway train and then takes his choice of two passageways, one leading to cars for Arlington, and one leading to cars for Mt. Auburn. A passenger desiring to go towards Boston alights from his car at the unloading platform and proceeds through a single passageway to the platform where he boards a subway train for Boston. In addition to this, it is, of course, possible to enter any of these loading platforms from the street at Harvard Square, or to leave any of the unloading platforms and walk up a stair-

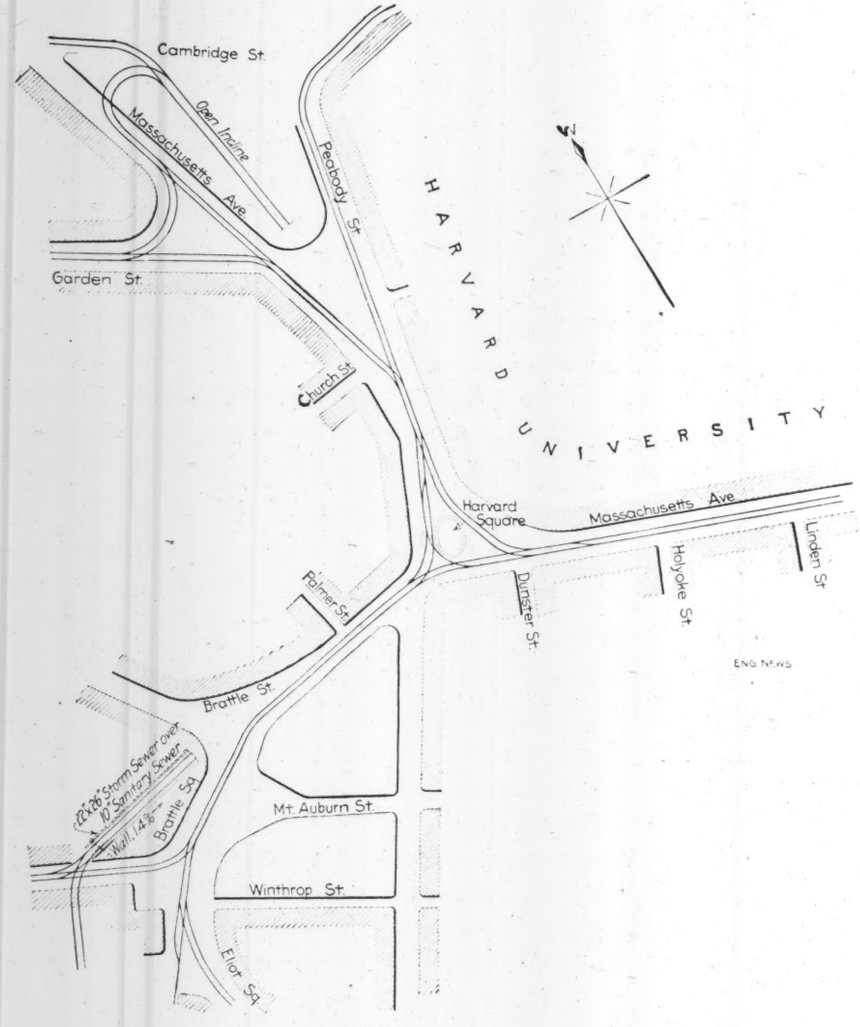


FIG. 4. PLAN OF SURFACE TRACKAGE AROUND HARVARD SQUARE TERMINAL OF CAMBRIDGE SUBWAY

way to the surface. It will be seen that the surface cars are run through from Mt. Auburn to Arlington and vice versa.

INTERMEDIATE STATIONS—The stations at Kendall and Central Squares, which are way stations between the two terminals, consist of concrete platforms on the outside of each track.

ROADBED

The subway is drained down a gutter on its center line as shown in cross-section in Fig. 3. The gutter is protected by short movable inverted half-pipes constructed of reinforced concrete and placed over the gutter. There are holes in the sides of these movable half-pipes to allow for ingress of water. In the subway there are six pump rooms and six ventilation chambers and emergency exits combined. A refuge niche is provided in each wall every 20 ft., the niches in opposite walls being staggered.

The tracks are laid in rock ballast. The ties are yellow pine, most of them having been treated, and the rails are 85-lb. A. S. C. E. standard T-rail. The curves for the train tracks are transition curves and the sharpest radius is 750 ft. The heaviest grade is 3% on the approach to the Cambridge Bridge. Every third tie is longer than the others, to form a support for the third-rail. A trolley wire is hung over each track for emergency purposes and to enable the current to be shut off from the third-rail in order that the necessary track maintenance work may be prosecuted without danger to workmen.

STATION FINISH—The station walls are lined with terra-cotta ribbed tile split in half, laying 2 in. thick against the concrete wall. The ribs are vertical, serving the double purpose of draining away any water which may percolate through the concrete and of allowing the air to circulate from the drain below up the spaces between the ribs and out at the top through ventilation blocks set in the plaster finish of the upper part of the station wall. A so-called "sanitary base" is used, exposing a curved surface at the junction of the wall and floor for the purpose of easy cleaning. The base has a granolithic finish similar to that of the

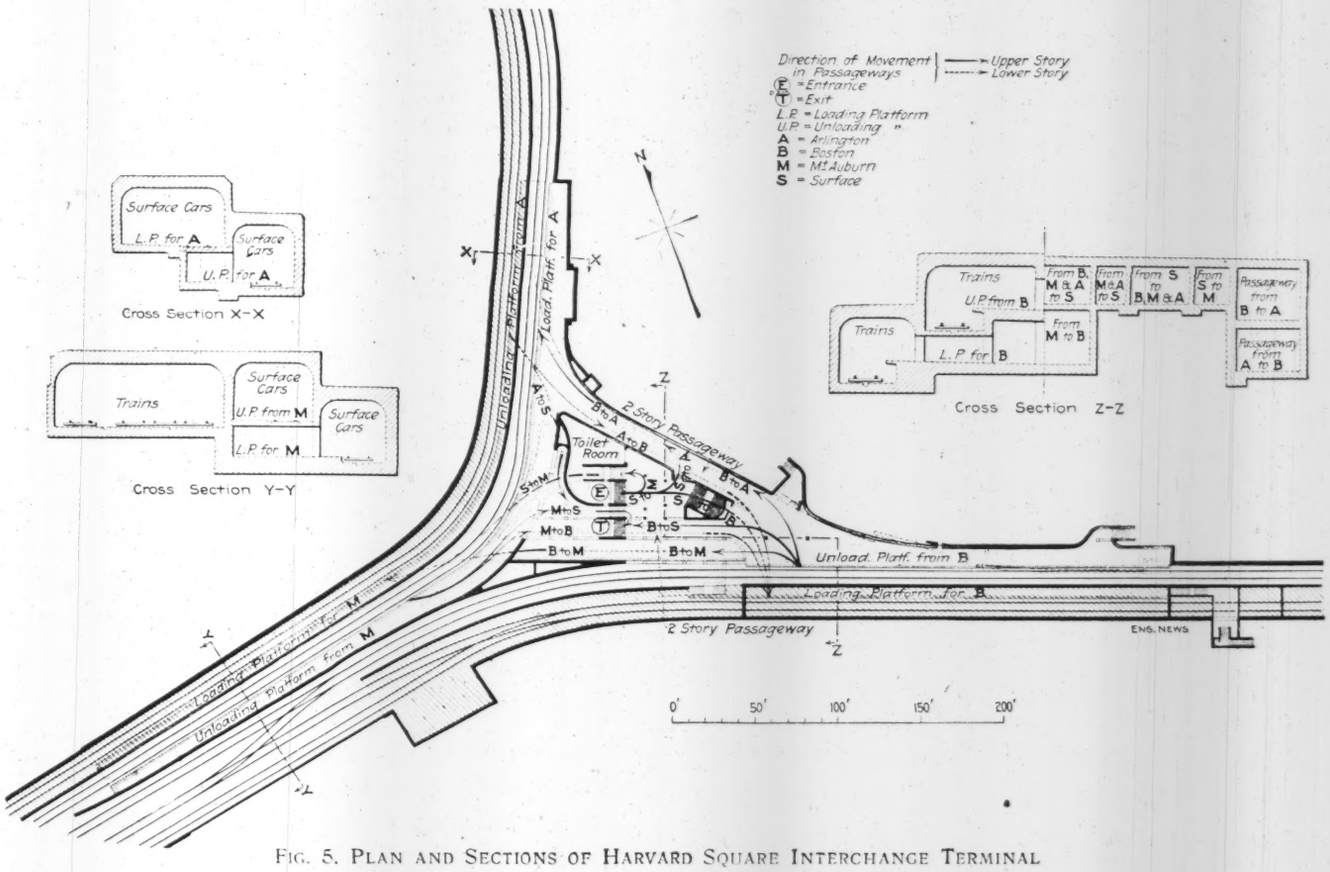


FIG. 5. PLAN AND SECTIONS OF HARVARD SQUARE INTERCHANGE TERMINAL

At Central Square there is an entrance and an exit at each end of each platform. Fig. 6 shows a cross-section of this station. The columns supporting the roof are 15 ft. on centers measured parallel to the tracks. It will be noticed that the edge of the platform overhangs about 3 ft. 2 in.; under this overhang on both sides are conduits. There are three entrance and three exit stairways 4 ft. wide, and one entrance and one exit stairway 6 ft. wide at this station. The station platform slopes away from the edge of the track by a gradient varying from ⅛-in. per ft. on the side next the track to ¼-in. per ft. on the side farthest from the track. A gutter for drainage is located at the lower side of the platform and drains are carried back across under the platform to the track.

The station at Kendall Square is similar in type to that at Central Square, but differs considerably in the arrangement of stairways. It is also characterized by the substitution of reinforced-concrete piers for columns to support the roof between the tracks.

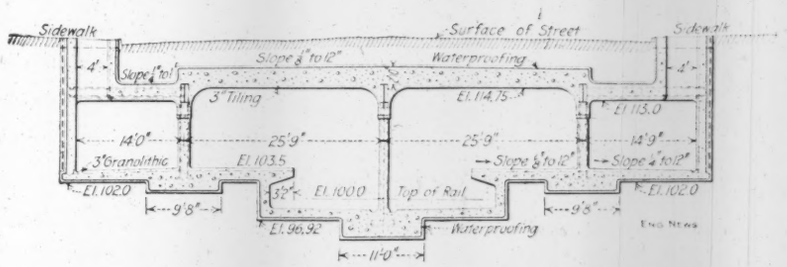


FIG. 6. CROSS-SECTION OF CENTRAL SQUARE STATION OF CAMBRIDGE SUBWAY

floor. Above this granolithic base white enamel tiles are set in plaster to a height of 6 ft. The tile trimmings are green at Kendall Square, buff at Central Square and red at Harvard Square. The wall above the enameled tiling and the ceiling are finished in white cement plaster.

There are some sidewalk lights in the stations, but generally artificial lights are relied upon.

The subway line is lighted by incandescent lights, so arranged as to be shaded from the eyes of an approaching motorman.

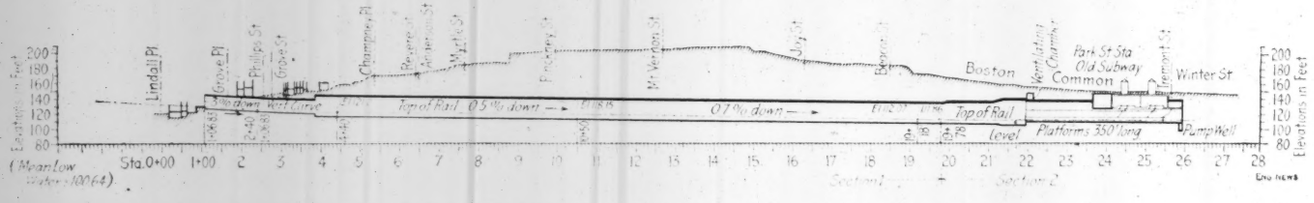


FIG. 7. PROFILE OF BEACON HILL TUNNEL SECTION OF CAMBRIDGE SUBWAY

ROLLING STOCK AND CARHOUSE

The cars which are to be used are about 70 ft. long and 9½ ft. wide. They are all steel, except the wooden window sashes and doors. The seats are longitudinal. One-third of each car is partitioned off by a steel partition with a double-leaved sliding door, so that it may be used for a smoking compartment. There are three doors on each side, so located that each one is substantially in the center of one-third of the car. These doors are to be used for entrance and exit indiscriminately. They are operated by air pressure controlled by electromagnets operated by the guard from buttons at either end of the car. An automatic mechanical lock is provided, which keeps the door shut without the necessity of holding it closed by air pressure. When all the doors are closed, an automatic starting signal is given to the motorman by means of a buzzer. A push button is located on the outside of the car beside each door, so that it may be closed by a guard standing on the station platform, but it cannot be opened by him.

The Westinghouse pneumatic multiple-unit control is used. There are two 200-hp. Westinghouse interpole motors on each car, both motors being mounted on one truck. The voltage used is 600. The airbrake is controlled either pneumatically or electrically. The electrical control consists of three needle valves, controlled by electromagnets energized by a storage battery. One of these electromagnets is for service application of the brakes, another for emergency application, and a third for release. The usual triple valve is provided, but when the electric control is used it does not move. The motorman may, however, use the brake as an ordinary automatic airbrake, and in case the train breaks in two the brake acts in this way. The magnetic control has the advantage that all the brakes are applied simultaneously.

The motorman's cab is so arranged that when not in use a seat is pulled up in it, and it can be used to accommodate passengers. The cars are lighted by forty 16-c.p. lights, arranged over the seats and through the center of the car, and are heated by 27 double-coil heaters.

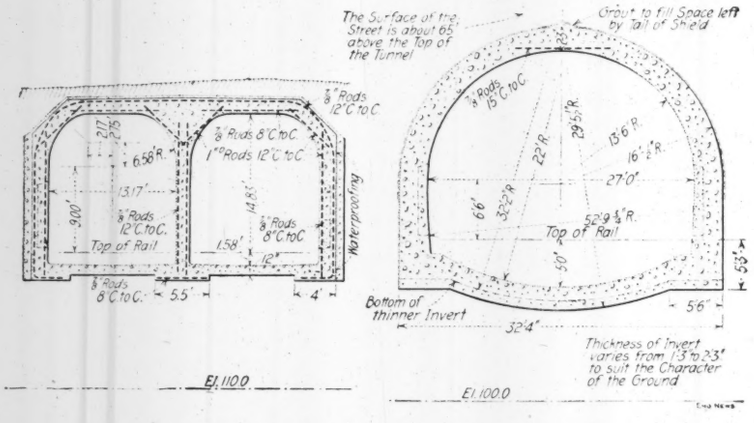

The Surface of the Street is about 65' above the Top of the Tunnel
Grout to fill Space left by Tail of Shield
Waterproofing
Top of Rail
Bottom of thinner Invert
Thickness of Invert varies from 1'3" to 2'3" to suit the Character of the Ground
El. 100.0

FIG. 8. CROSS-SECTIONS OF BEACON HILL TUNNEL

Automatic couplers are used, and the drawbars are so arranged that the coupling of the air-hose is automatically performed.

The Eliot Square carhouse occupies a space about 625×335 ft. At one side is a machine shop with three tracks in it. Next, there are five tracks for inspection purposes provided with pits running their whole length. Next, there are six tracks for storage of cars, and beyond this is room for three more tracks which may be added at some future time. The machine shop and inspection tracks are covered, but the six storage tracks will be open. Footings have been put in for columns between these tracks, so that if found desirable they may be roofed over at a later date.

There is a loop track running completely around the carhouse, with a special platform on Boylston St. intended to accommodate crowds to and from football games at the Harvard Stadium, which is a short distance away along Boylston St. It is not intended to use this platform for passengers at any other time. There is also a connection with the surface-car tracks, so that surface cars may, if desirable, be repaired in the machine shop.

The Hugh Nawn Contracting Company, Harry P. Nawn, President, was the contractor for the subway and tunnel work in Cambridge. The contract was a "percentage-bonus-fine contract," and provided that the elevated should pay the cost of the work to the contractor, except for his personal services, small tools, etc., and, in addition, a fixed percentage. The contractor received, under the contract, a bonus arranged on a sliding scale for completing the work for an amount less than the engineer's estimate. Had the cost exceeded this estimate, he would have been required to pay a fine.

This work was constructed under the direction of Mr. George A. Kimball, Chief Engineer of the Boston Elevated Railway Company. The Designing Engineers were Messrs. E. R. Springer and Frank H. Carter. Messrs. F. B. Edwards, W. O. Wellington and R. B. Farwell were Division Engineers in charge of construction. Mr. Seth Peterson and Mr. E. E. Albee were in charge of the relocation of sewers and water and gas mains, respectively. Mr. P. F. O'Brien was in charge of the finish of the stations.

BEACON HILL TUNNEL

The Beacon Hill Tunnel, about 2500 ft. long, is shown in profile in Fig. 7. About 300 ft., extending from the portal at the western end, was built in open cut, as it was at or near the surface of

the ground. This work involved supporting, cutting through and underpinning several buildings, most of which were comparatively small. From the end of this portion to a point about 210 ft. from the Park Street Station, the construction was carried on by means of a roof shield without using compressed air.

The material encountered was, in general, a very hard mixture of sandy clay, with numerous small stones and occasional boulders. Some irregular veins and pockets of sand, carrying small quantities of water, were encountered. This sand hindered work somewhat by caving in, but the difficulties were not serious enough to necessitate the use of compressed air. The shield weighed about 65 tons, and was propelled by fourteen 8-in. hydraulic jacks of a capacity of 80 tons each, with a maximum working pressure of 4000 lb. per sq.in.

The method followed was, in general, similar to that used in the Cambridge portion of the subway, as described above. The sidewalls were kept about 200 ft. in advance of the shield, and the invert was put in about 100 ft. behind the shield and arch. The normal progress of the shield was from 45 to 50 ft. per week. The surplus earth was removed from the tunnel, and all necessary materials were taken in through a shaft at the intersection of Phillips and Grove Sts., which is about in the middle of the portion completed in open cut. Only the portion of this section which was built in open cut was waterproofed.

Fig. 8 shows sections of the tunnel in open cut and tunnel portions, respectively. Fig. 9 contains cross-sections through the Park Street Station. Fig. 10 is a photograph taken in the Beacon Hill Tunnel on Nov. 11, and shows the tunnel with the track partially completed.

From a point about 210 ft. west of the Park Street Station the section of the tunnel was gradually enlarged to permit the necessary spreading of the tracks to accommodate the island platform at the station. Because of the tapering section at this point, it was impracticable to use the shield. A shaft was sunk in the Common 18 ft. long, as wide as the tunnel, and about 50 ft. deep, at the beginning of this section. The headings were started from this shaft, and all the material was handled through it.

The method followed was to drive two

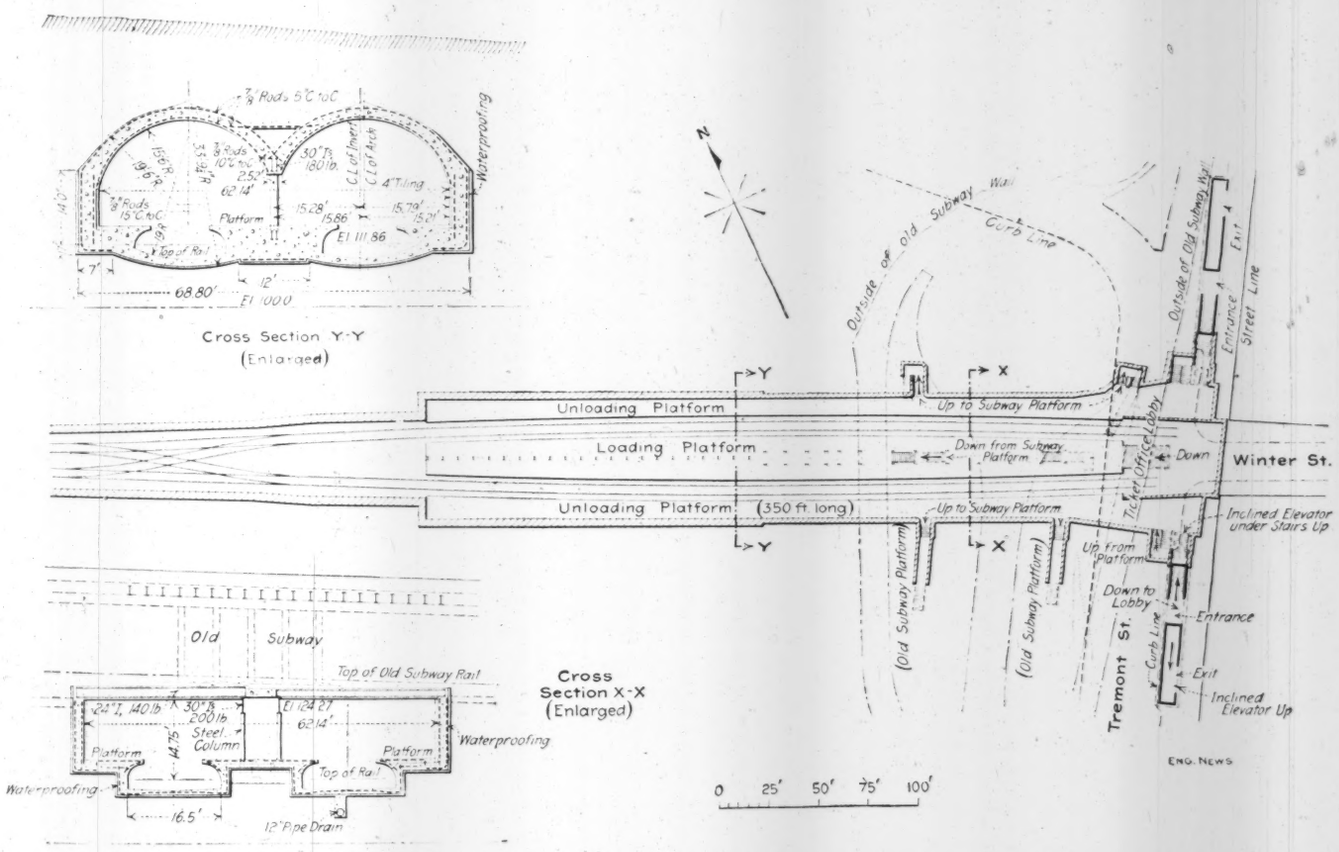
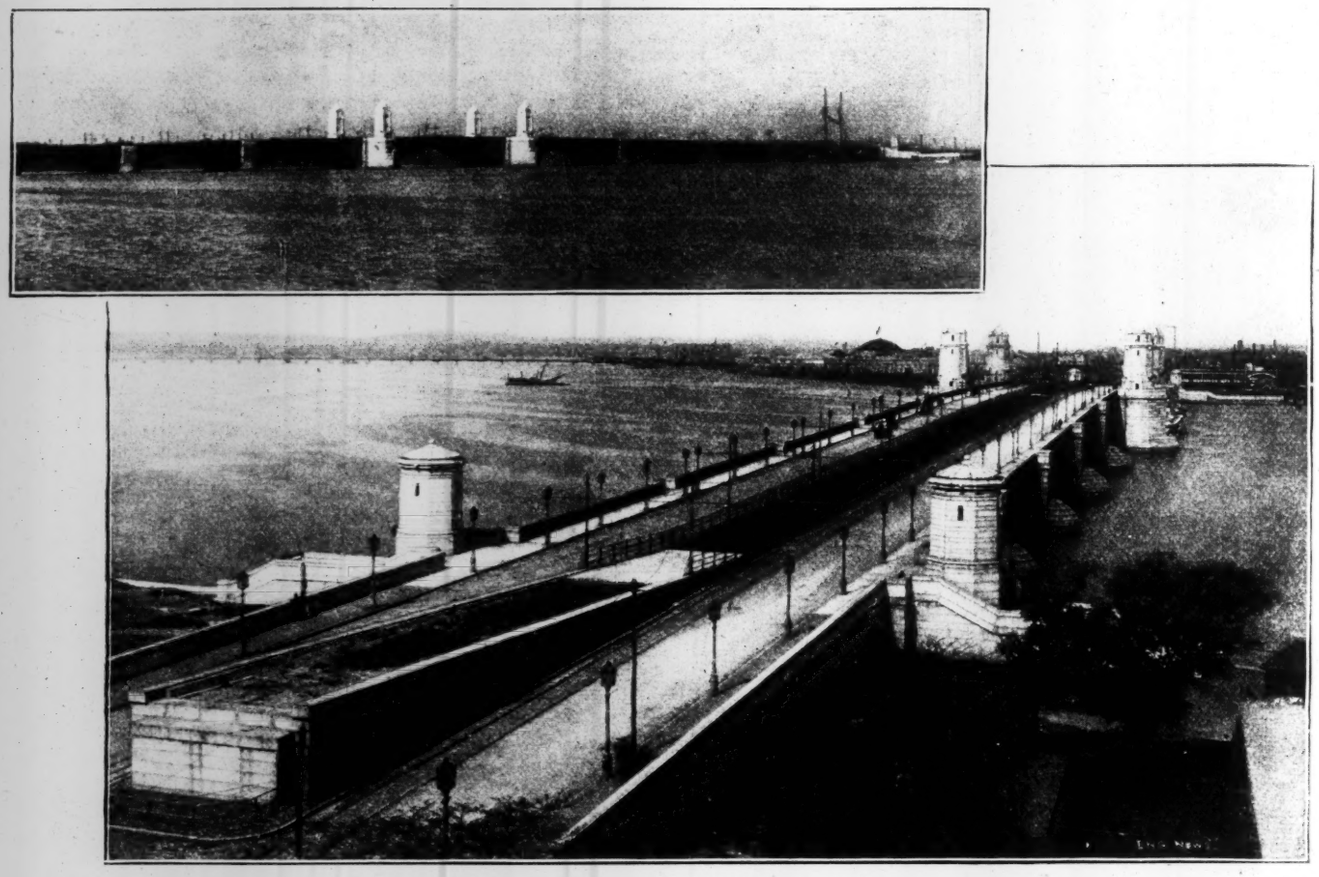


FIG. 9. PARK STREET STATION (BOSTON TERMINAL) OF CAMBRIDGE SUBWAY

FIG. 10. VIEW IN BEACON HILL TUNNEL
(Photograph taken Nov. 11, 1911. Tracklaying not completed.)



FIGS. 11 AND 12. THE CAMBRIDGE BRIDGE

(Cambridge Subway crosses the Charles River on this bridge. The view from the Boston end shows the location of tracks and the incline to the viaduct leading to the west portal of the Beacon Hill tunnel.)

headings, one on each side of the tunnel, about 6 ft. high and 12 ft. wide, with the top of the heading at the level of the top of the side wall. These headings were then deepened to a total height of 20 ft., this deepening of the heading following 10 to 20 ft. behind the upper heading. The sidewalls were then built. A crown heading was driven at the same time as the side headings. The ground between the crown and side heading was then excavated to the outline of the outside of the arched roof and lagged, this lagging being supported by braces on the core of undisturbed earth in the central portion of the tunnel. The successive pieces of this lagging were beveled in such a way that the lagging already in place supported the back end of the new portions until the proper bracing could be put under it.

The lagging formed the outer form for the concrete tunnel arch. The inner form was built and supported upon the undisturbed earth core. This method of construction made it possible to throw the concrete into the forms from the face of the tunnel instead of from the crown, which considerably simplified the operation.

The core was dug out and the invert was placed last.

The portion of the tunnel under the Common was carefully waterproofed, both to make the tunnel dry and to preserve the level of the groundwater in the Common in order to avoid injury to the trees. The waterproofing of the tunnel arch consisted of two layers of "Minwax" saturated cloth alternating with three layers of "Minwax" waterproofing. The sidewalls were constructed with an outside protective wall 8 in. thick, inside of which was placed four layers of tar paper, each layer mopped with pitch. The main sidewalls were then built inside this waterproofed protective wall.

PARK ST. TERMINAL—Fig. 9 gives a plan of the new Park St. Station. The outlines of platforms and walls in the old station, which is above and generally at right angles to the new one, are shown in the drawing. The new station has been built with a view to its use as a through or way station when the subway is finally completed to South Boston. As stated above, it is below the level of the present Park St. Station of the Tremont St. Subway. It is a two-track stub-end terminal. There is a loading platform between the two tracks, and there are unloading platforms outside of each track. For the present, trains will run into the station, passengers will leave by way of the unloading platforms, and the passengers wishing to go to Cambridge will board the train from the loading platform in the center. The motorman will change ends and the train will then be switched to its proper track and will return through the subway. By reference to the drawing it will be seen that stairways are provided so that passengers may pass from either unloading platform up to either of the platforms in the old Park St. Station, or to Tremont St. by means of an escalator. Passengers may also pass from either of the platforms in the old station down stairways to the loading platforms between the tracks. The stairways connecting the old and new stations are intended to be used for the transfer of passengers. Direct entrance from the street is by means of two entrance stairways shown on Tremont St. These stairways lead to a lobby and ticket office above the tracks of the new subway, from which passengers descend by a stairway to the loading platform between the tracks. By this means the incoming and outgoing passengers are kept entirely separated at all times.

The actual construction of this station beneath an existing one without disturbance to traffic in the existing station was a difficult and slow undertaking. The

method followed was first to construct the new station as completely as possible under the old one, shoring up the invert of the old subway, now become the roof of the new one, by means of timbers placed 3 ft. apart in both directions. The new subway was constructed completely up to the beam seats which carry the beams supporting the floor of the old subway. Strips of varying width running the full width of the new subway were then cut out of the floor of the old station and the roof beams were lowered through these cuts to their places on the walls of the new subway. These beams were brought in and placed through the old subway during the night. The roof of the new subway was then constructed on these beams in its permanent position, supporting the tracks and platforms of the old subway.

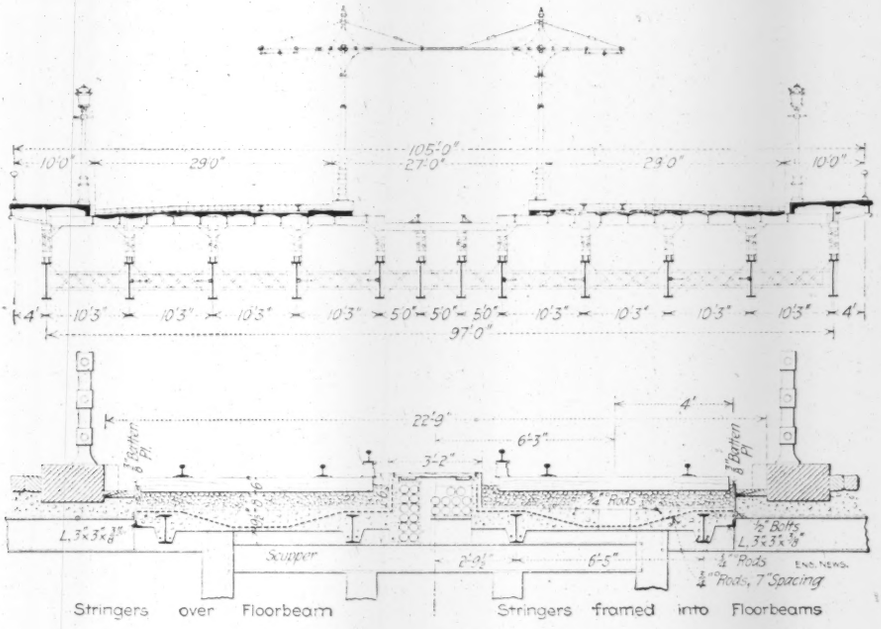


FIG. 13. CROSS-SECTION OF CAMBRIDGE BRIDGE

The length of this station is about 350 ft. It is double-barrelled in cross-section for about one-half of its length. An overhead chamber, about 45 ft. wide, to provide for a connection with the then proposed Riverbank Subway, was built just west of the old Park St. Station. This chamber may be used in connection with the proposed Boylston St. Subway which was authorized by the last Legislature to take the place of the above-mentioned proposed Riverbank Subway.

The contractor for Section 1, comprising the open cut and shield portions of the work was Patrick McGovern. Coleman Brothers, contractors, constructed Section 2, which included the rest of the tunnel and the Park St. Station. The work was done under the direction of Boston Transit Commissioners George G. Crocker, G. F. Swain, H. G. Allen, Josiah Quincy and J. B. Noyes, Chief Engineer Edmund S. Davis and Consulting Engineer Howard A. Carson. The division engineers were G. Dana Emerson and Wilbur W. Davis, in charge of Sections 1 and 2 respectively.

THE CAMBRIDGE BRIDGE

The Cambridge Bridge, over which the elevated trains run in passing from the Cambridge to the Boston portions of the subway, is shown in the photographs Figs. 11 and 12. It is a combined railway and highway bridge 105 ft. wide, 1767½ ft. long between abutments, and nearly one-half mile in length, including abutments and approaches. The profile provides for a 3% gradient on both sides of the center with a vertical curve 800 ft. long over the central portion.

The bridge consists of eleven steel arch spans varying in length from 101½ ft. at the abutments to 188½ ft. at the center, and in rise from 8½ ft. to 26½ ft. Each arch span consists of twelve two-hinged steel arch ribs of I-shaped plate-girder section which vary in depth from 3 ft. in the shortest spans to 4½ ft. in the center or longest span. The spacing of these ribs is shown in Fig. 13, which gives a cross-section of the roadway and shows the construction finally adopted for the railway portion. The roadway is carried by vertical posts which rest upon the top flanges of the ribs, and their longitudinal spacing is the same in all spans, the difference in length of the spans being in all cases a multiple of the distance apart of the posts.

The view Fig. 12 is taken from a point above and to the right of the Boston end of the bridge and shows very clearly the location of the railway tracks on a reservation in the center of the bridge and separated from the roadway on either side by a heavy iron railing. The stone walls enclosing an earth fill and rising in the foreground are for the connection to the elevated structure, which extends from this point to the portal of the Beacon Hill Tunnel. The four lines of I-beams which support the railway tracks on the bridge are very clearly shown in the photograph.

The bridge spans are supported on ten masonry piers and two massive abutments. The foundations of the piers are very massive. They are from 150 to 200 ft. long, and from 36 to 67 ft. wide, and are supported on piles driven into boulder clay overlying bed rock. The two large central piers are 53 ft. wide at the coping and 188 ft. long. These two piers are of cellular construction, the granite facing on the sides being backed with concrete which has a total thickness of 10½ ft. at the coping. The sides of the piers are connected on the lines of the ribs and skewbacks by smaller walls of concrete 5 ft. thick, which transmit the thrust of the arches to the foundations. In general, the masonry consists of substantial outer walls of granite with concrete interior walls.

The writer wishes to express his appreciation of the kindness of Mr. Kimball, and his staff, of the Boston Elevated, of Messrs. Swain and Davis, of the Transit Commission, and of Mr. F. H. Fay, Deputy Commissioner of Public Works of the City of Boston, in furnishing information, cuts and photographs from which this article was written.

Development of the Philippine Islands in the dozen years of American occupation is well shown in the annual report of Gen. Clarence R. Edwards, Chief of the Bureau of Insular Affairs. The imports have increased from about $20,000,000 in 1900 to nearly $50,000,000 in 1911. About two-fifths of the imports came from the United States. The export trade of the island has increased in almost as great a ratio, from a little over $20,000,000 in 1900 to nearly $40,000,000 in 1911.

A Tool Box Built on Skids is described by James W. Beebe in "Engineering and Contracting" for Jan. 10, 1912. Mr. Beebe states that the box has proven satisfactory and is easily handled by one man and a team. He continues his description as follows:

The box proper is made 6½ ft. long inside by 3 ft. wide, 2½ ft. high in front and 4 ft. high behind. All measurements except the first are outside dimensions. The small box increases the length about 2 ft. and is 2 ft. high on the low side. The runners should be of 3x8 in. by 10 ft., with eye-bolts, so the box may be pulled from either end. The upright posts are of 2x4-in. pieces and extend 6 in. down alongside the runner. The ones at the rear of the box are brought 6 in. above the top to support the lid when open. The 2x4-in. pieces on which the floor is laid are let into the runners at least an inch and are spaced when possible so the uprights are directly against them. This construction makes a very strong box that may be handled very roughly without damage. The smaller compartment is especially convenient for nails, oil cans and small tools.

Tests of Coal Tar Paint*

In 1901, A. B. Cunningham, civil engineer U. S. Navy, originated a coal-tar paint for protecting iron and steel work. He was at that time stationed at New Orleans Naval Station in charge of the floating dry-dock and the idea of using coal-tar as the basis of a paint was suggested by the river craft about New Orleans which used raw coal-tar on their submerged portions. However, there were objections to the use of raw coal-tar since it never permanently set and was very apt to run at high temperatures and to crack (alligator). Moreover, it contained some un-neutralized acids, which were apt to attack the steel. It is claimed that the paint finally devised embodied the good features of raw coal-tar but eliminated the undesirable ones mentioned. As described by Mr. Cunningham in ENGINEERING NEWS, July 12, 1906, it is composed of coal-tar, kerosene and portland cement in proportions of 8:1:1 to 16:4:3.

This paint has been used on the submerged pontoon of the floating steel dry-dock at New Orleans, on the floating steel dry-dock "Dewey" in the Philippines, at the Government naval stations in New York and Key West, and as a roof paint on the buildings in the Panama Canal Zone.

The paint was devised originally for use on metal surfaces but has been used for protecting wood, and to a limited extent for waterproofing brick and concrete work.

In order to obtain data on the waterproofing properties of such paint extended tests were carried out as outlined below. Briefly stated, they consisted of comparing the holding qualities of a concrete tank, painted and unpainted.

The tank was 12 in. square outside and 18 in. high. The inside was 13 in. deep, 4 in. square at the bottom, and 7 in. at the top. It held 394 cu.in. of water and when full had 304.5 sq.in. exposed to the water.

The concrete was made up of one part portland cement, three parts sand and six parts of well assorted gravel; it was mixed rather wet to insure close packing. This is the leanest concrete that is used by yards and docks for mass concrete and is very porous. The tank was covered with a wooden cover having a soft packing on the underside in order to prevent evaporation.

TEST NO. 1—An empty, unpainted tank was immersed in a bosh of water. The water which crept through rose 7 in. in the first 24 hours and in the next 24 hours the tank was entirely filled. That is, 394 cu.in. of water leaked through in 48 hours, or 8.2 in. per hour.

This tank was removed, thoroughly dried and filled with water. It was found that 6 in. of water leaked out during the first 24 hours and the tank was empty at the expiration of the next period of 24 hours. This showed that the outward leaking and infiltration took the same length of time.

TEST NO. 2—The same tank was thoroughly dried and then the outside was given one coat of coal-tar paint. After this had dried a second coat was applied. The total surface painted was 1008 sq.in. (7 sq.ft.). The paint required for the application of the two coats was a little less than one pint; 60% of this amount was used on the first coating and the remainder, 40%, was used on the second coat.

This tank, painted on the outside, was then placed in a bosh of water, and carefully observed so that the slightest infiltration would be noticed. After 755 hours, the tank was removed; the inside was perfectly dry, not even showing a trace of dampness. The reason for removal at this time was the necessity of making another test with the same tank (Test No. 4).

TEST NO. 3—A tank was painted on the inside and then filled with water. After standing for one week, there was no trace of a leak, and it was very evident from the dry outside that no water had come through. For comparison it should be noted that in the previous test of an unpainted tank, under similar conditions, 394 cu.in. of water leaked out in 48 hours. The above tests were for the pressure of the water directly against the paint. The following one was made to study the effect of water on the under side of the paint where the film would be forced away from the concrete wall instead of against it.

TEST NO. 4—The tank which had been used for Test No. 2, (painted on the outside) was filled with water. After 106 hours no leakage was shown, even though the water did not press directly against the painted surface.

The tank used for Test No. 3 (painted on the inside) was then placed in a bosh of water. After 118 hours there was no evidence of infiltration.

PRESSURE TESTS—The above tests were repeated under increasing heads which were secured by bolting the covers on watertight, screwing a pipe through them, and connecting to a test pump which drew water from a reservoir in which the amount drawn could be easily measured; the readings of leakage tabulated below were taken at one minute intervals and each represents the total up to the time of reading.

TEST NO 5—An ordinary, unpainted, tank was connected to the test pump as described above. The tank burst at a pressure of 28 lb. per sq.in.; the leakage was as shown in the table at the top of the next column.

Pressure; lb. per sq.in.	Equivalent head; ft.	Water leaked through; cu.in.
5	11.5	3
10	23.0	18
15	34.5	65
20	46.0	214
25	57.5	432
28	64.5	631

TEST NO. 6—The tank used for Test No. 2 was used (painted on the outside). It did not pass water until subjected to 22 lb. per sq.in.; it burst at 50 lb. per sq.in. The leakage is given below.

Pressure; lb. per sq.in.	Equivalent head; ft.	Water leaked through; cu.in.
5	11.5	0
10	23.0	0
15	34.5	0
20	46.0	0
22	50.7	2
25	57.5	57
30	69.0	123
35	80.5	212
40	92.0	296
45	103.5	318
50	115.0	431

TEST NO. 7—This test was made with the tank that was used for Test No. 3 (painted on the inside). It did not commence to pass water until under a pressure of 35 lb. per sq.in.; the breaking pressure was 74 lb. per sq.in.

Pressure; lb. per sq.in.	Equivalent head; ft.	Water leaked through; cu.in.
10	23.0	0
20	46.0	0
30	69.0	0
35	80.5	3
40	92.1	47
50	115.0	136
60	138.0	211
70	161.0	287
74	170.4	365

The Use of Coasting Clocks on cars of the Chicago Railways Co., to secure closer attention of motormen to maximum coasting, is the subject of a recent report by Mr. J. D. Elsom, engineer of tests. The coasting-time recorders were installed on 50 steel prepayment-type cars operating on the Van Buren St. line, and tests were carried on continuously from Feb. 25 to July 1, 1911. Before the clocks were installed a five-weeks test of power consumption was made for comparison with expected results. This line was selected for equipment as being the one where it was most difficult to coast, on account of narrow streets, congestion of street traffic and a fast schedule. An average saving of 15.6% in power for propulsion and of 40.8% in brake shoes was found. The estimated annual saving on this line (based on actual savings during test periods, was $7782 for power and $562 for brake shoes. The interest on cost of extra equipment, supplies, etc., amounted to $1925, leaving an estimated net income of $6419, a return of 122.2% on extra investment. The same rates applied to the entire system of the company, on a basis of car-miles and kilowatt-hours (at 1c. per kw.-hr.), showed a gross annual saving of $284,188 for power, and $22,472 for brake shoes. The annual cost of the clocks would amount to $40,868, a saving of $265,792.

Moreover, it was found that the 15.6% saving in energy resulted in a 14% reduction of station peak loads. The clocks enabled detection of inefficient motormen, and it was found that these men used about 82% more power than the better men through sudden and ragged acceleration.

*From information furnished by Mr. F. P. Barrett, Manager of the Paint Department, Maryland Steel Co., Sparrow's Point, Md.

A 1000 H.P. Gas Turbine

A 1000-hp. internal-combustion turbine, described by H. Holzwarth before the Schiffenbautechnische Gesellschaft at Berlin, Germany, on Nov. 23, 1911, is shown in the accompanying figure (reproduced from London Engineering of Nov. 24, 1911). As in previous designs, a mixture of gas and air is exploded in a chamber, expanded in nozzle outlets, and caused to flow against the blades of a turbine wheel to convert its velocity energy into mechanical work. Separate compressors are required to supply gas and air, and a pump is needed to maintain a vacuum at the exhaust.

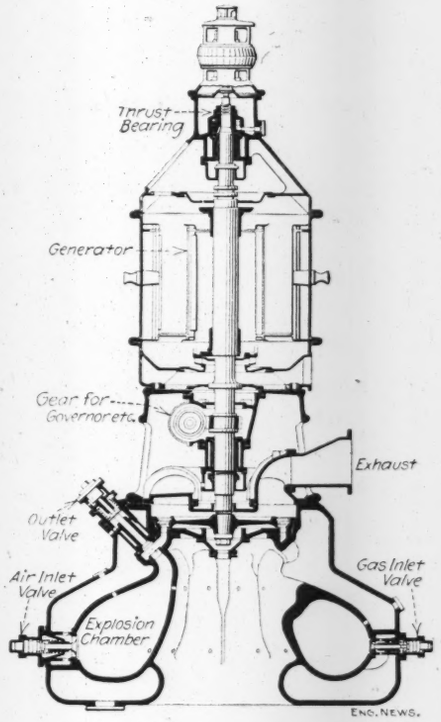
The stomach-shaped explosion chambers are arranged in a circle in a cast-iron base. A vertical turbine shaft is used, being supported only at the top by a thrust bearing, but with a guide bearing below to preserve alinement. This method of design permits accomodation of expansion of the turbine parts. It is reported that smooth running has been obtained at all speeds, although the turbine casing has reached a temperature as high as 500°C. The exhaust is piped through a regenerator where it is made to evaporate the water needed as steam to run the auxiliaries. The surface of the regenerator is practically the same amount as that in the condenser of a steam turbine of like capacity.

The several valves are of poppet type, but governed by oil pressure under small pistons on the valve spindles. The oil is furnished by a rotary pump on the governor shaft, which also drives the governor, a tachometer and an ignition timer.

It is claimed that the machine shown in the accompanying figure has less than one-third the floor space needed for a reciprocating gas engine of the same capacity and less than one-fourth the weight.

In operation, an explosion chamber is first filled with air and then gas is forced in. On ignition (methods not given further) the inlet valve is shut and the outlet valve forced open by the explosion. The gases rush out and expand in proper nozzles before flowing through the blade passages. As the combustion-chamber pressure drops off, the outlet valve is forced to its seat by a spring, but its action is regulated by oil pressure under a controlling system, so that the valve remains open long enough to insure good scavenging by the incoming air of the succeeding charge. The cycles of operation in the different explosion chambers are so timed that the explosions follow each other around the circle. The engine as designed is to develop an explosion pressure of only about 150 lb. per sq.in. and to maintain the temperature of gases through the blading at less than 400° C.

Rapid combustion, but not detonation, was desired. On light loads, no trouble was found, but with heavy fuel charges needed for greater loads the temperatures rose above the expected figures and detonation of the full chamber contents occurred. On carrying loads and fuel charges higher, an explosive wave developed which caused combustion to take place partially among the turbine blades. By abandoning air cooling, substituting water jackets for the free heating spaces above and below the combustion chambers, and by taking air and gas directly through the inlet valve, difficulties mentioned were removed for all loads. This was done, however, at some expense of efficiency.



SECTIONAL ELEVATION OF A 1000-HP. GAS TURBINE

(Built by Brown, Boveri & Co., for H. Holzworth, Mannheim, Germany.)

It was stated that earlier work on smaller units and the tests of this larger one at light loads showed an expected total-efficiency curve rising from about 20 to 30%. The actual performance has fallen short of the expected at the larger loads on account of the heavier losses due to adding the water jacket mentioned above as necessary to eliminate combustion troubles.

No trouble has been found at any time with erosion of the turbine blades, which is explained by the dryness of the gases passed through.

The machine shown in the accompanying figure was built to the author's plans by Brown, Boveri & Co., at Mannheim, Germany.

A Song of the Rail-Joint

A lyric poem on warts would hardly be enthralling. The ordinary man fails to find romance in warts, or corns, or rail-joints, which so far as troublemaking is concerned may be called the corn on the rail. Yet we find in the shadow of the new year that an uptodate verse-smith has boldly made the rail-joint and its alleged music the theme of a poem.

We print the poem below for the edification of those of our readers who know whether suspended joints are better than supported joints or not and the difference between their music.

Curiously enough, the author of the poem, Damon Runyon, calls it "A Ballad of the Brake-Beams." But brake-beams play only a sentimental part; the singer of the song which he has put into words is the humble rail-joint, which to the eye appears stationary and silent.

Do you know what a freight train says
to a guy
When he's ditched, and it goes rumblin'
by?
Rumblin' along it sings a song, and this
is the song it sings so high:
Ham-gazzam-gazzam-gazzam!

Do you know what it means to a travelin'
gent
When he's t'run from a train, and broken
and bent
He lies there hurt, in the dust and dirt,
while the train sings back from the
way it went?
Ham-gazzam-gazzam-gazzam!

Do you know what it is to suffer from
cold,
From thirst, and hunger, and then be
rolled
Offen a deck on the back o' your neck,
while the song comes back where the
miles enfold?
Ham-gazzam-gazzam-gazzam!

Do you know when a freight train hits
a switch
Wit' a roar and a slam and a snaky
twitch—
The hymn so grim it sings to him as he
lays watchin' it from the ditch?
Ham-gazzam-gazzam-gazzam!

That's what a freight train says to a guy
When he's ditched wit' a boot from a
brakeman spry—
Cussin' his luck he lays there stuck 'till
another train comes a-rumblin' by—
Ham-gazzam-gazzam-gazzam!

[From the "New York American"]

The Standardization of Vitrified Sewer pipe was the subject of a paper read before the recent meeting of the British Institute of Sanitary Engineers, by Mr. James Farley, Vice-President of the Institute. Nine suggestions for standardization were suggested, most of which were beautifully indefinite. The author proposed that pipes should be kept within "a certain limit as regards deviation from straightness"; that the diameter "must not vary beyond a fixed margin"; that the joint space should be "uniform and suitable"; that the thickness "must not be less than the minimum"; that the pipes must be "nonporous," "capable of standing a proper pressure," "must not exceed a fixed margin of expansion between freezing and boiling points," and "must not be liable to disintegration." The only definite suggestion in the whole nine was that "all pipes must be branded." The author stated that the British Engineering Standards Committee, appointed some ten years ago by the Institution of Civil Engineers, is endeavoring to establish a standard for the manufacture of vitrified sewer pipe.

Catskill Aqueduct Control Valves

By James Owen*

In seeking a suitable type of 48-inch valve for regulating the flow of water at the headworks of the Catskill Aqueduct, New York, the engineers finally chose a "needle-valve" design.

The valve is operated by an electric motor arranged for automatic control by means of a five-pole switch. Limit switches are provided to stop the motor at the full open or closed position.

The specifications for the valve materials, which gave good results, are given in the article.

*Assistant Engineer Designer, New York Board of Water Supply, 165 Broadway, New York City.

The development of gravity systems of water supply may be considered as consisting of two basic operations, namely, storage of water and control or regulation of its flow to serve the purposes for which it is to be used. The rate of flow of water from a reservoir is usually controlled by gates or valves which are minor details in point of cost as compared with a main structure such as a masonry dam, but which are, nevertheless, important for the convenient and proper operation of the works. The purpose of this article is to describe the controlling valves now ready for installation at the headworks of the Catskill aqueduct, with some of the considerations which led to the evolution and adoption of their design.

The function of these valves is to regulate the quantity of water admitted to the aqueduct to suit varying demands. They will be located in what is known as the lower gate chamber, one of the group of structures forming the headworks of the Catskill aqueduct. A controlling valve is essentially different from a stop-gate in that it is usually used partly open, and there are difficulties inherent to the operation of an ordinary gate valve in this way. A gate valve open a few inches presents a crescent-shaped opening through which the water under any considerable head impinges at high velocities on the invert portion of the pipe immediately beyond the valve, where it may cause erosion and consequent thinning of the metal. The renewal of such pipes may be attended by considerable difficulty and expense.

In considering this objection, the use of a pipe invert formed of removable manganese-steel plates was proposed but abandoned as a subterfuge rather than a real solution of the problem. The determination was then made to design a valve having a central opening, an early idea being to make it something on the order of the iris light-diaphragm of a camera. This did not seem mechanically feasible, but several studies were made for the purpose of designing a valve that would give a central delivery of water when partially opened by using two overlapping stop-plates or disks, sliding past each other and arranged to form a variable orifice at or near the center of the waterway. The size of the orifice would be regulated by vertical movement of the stop-disks from the closed position to wide open, when the full size of the 48-in. circular waterway would be attained. The stop-disks would run on vertical guides similar to those of an ordinary gate valve.

A valve of this type would fulfill the condition of central delivery when partly opened, but would probably be liable to the serious objection of "chattering" or vibration of the stop-disks on their guides. The chattering tendency of partly open valves is a more or less well known phenomenon and has given trouble in some notable water-works installations. In one case where 24-in. gate valves were used to throttle the flow, the resulting vibration broke off the flange bolts of some appurtenant connections. These considerations led to the ruling out of the flat-plate or disk principle of design.

The suggestion that a needle type of valve could be designed to meet the conditions came from Arthur West, consulting mechanical engineer to the New York Board of Water Supply. Preliminary studies were started and a final design believed to be satisfactory was rapidly

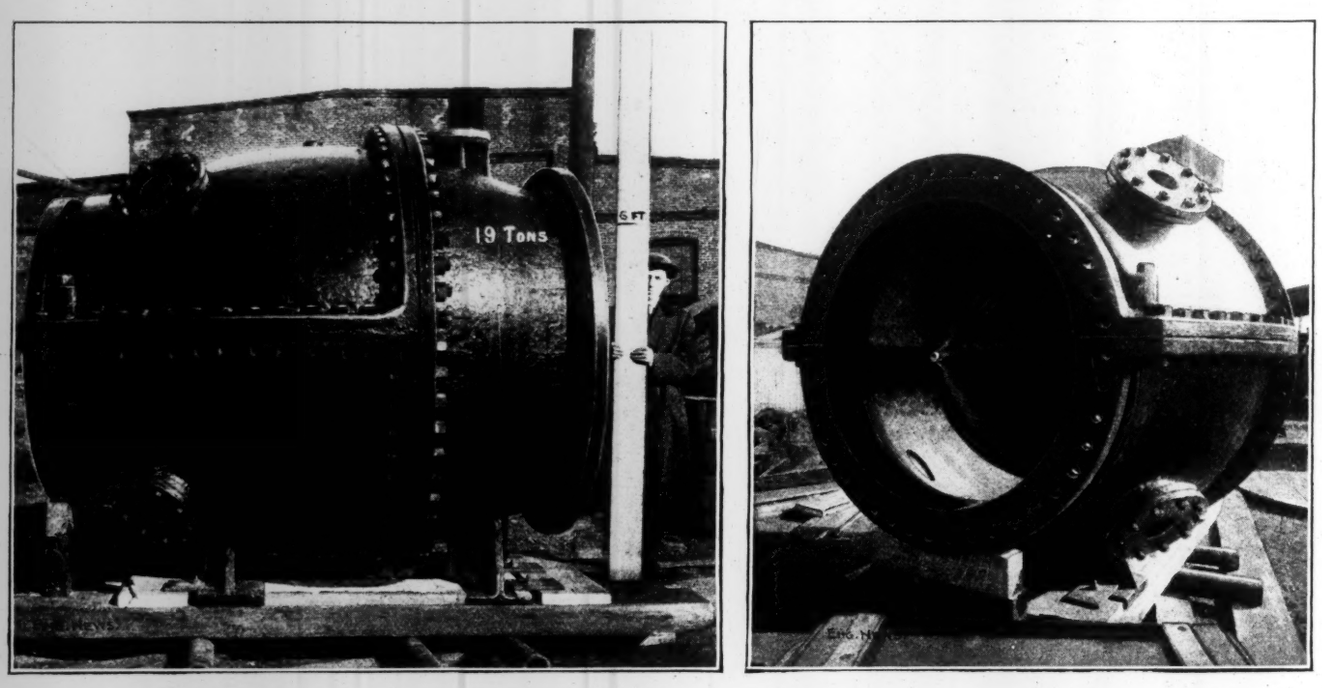


FIG. 1. TWO VIEWS OF ONE OF THE 48-IN. CONTROLLING VALVES FOR THE CATSKILL AQUEDUCT

evolved. One of the valves as eventually constructed is shown in Fig. 1.

Construction

The construction and working principle of the valve will be apparent from Fig. 2. It consists essentially of a body or shell containing a projectile-shaped plug moving horizontally. The closure is effected by the seating of the plug against the downstream neck of the shell. Although spoken of as a needle, the plug is a rather grotesque evolution, on account of its size, from anything like the usual needle or spindle of this type of valve. The plug is operated by means of a horizontal screw stem, planed bevel gears and a vertical drive shaft. The gears are mounted and inclosed in a chambered spider casting which takes the screw thrust and which has an extended neck to assist in guiding the plug. The shell is provided with a 4-in. drain valve.

The entrance opening of the valve is 60 in. in diameter and the body is swelled to form an annular waterway with area slightly in excess of that of the 48-in. discharge opening, the object being a gradual and only slight change of velocity of water in its passage through the valve. The maximum static working head to which these valves will be subjected will be 100 ft. A heavy design was adopted out of regard for corrosion, to take care of vibration, should there be any, and to be in keeping with the substantial character of the other Catskill works and appurtenances.

A somewhat novel feature is the vertical drive-shaft stuffing-box which is designed to permit the packing to be renewed while the valve is under pressure. The gland casting is enlarged and provided with a ring having diffusion channels leading up and out to an annular space which has a 3-in. drain outlet. The purpose of the diffusion piece is to divert leakage away from the stem while the packing is being placed.

The valve is bolted to an expansion piece (shown in Fig. 2) having a manhole and a special spigot end which fits the extra long bell of a special wall casting. The expansion-piece spigot may be pulled into this long bell by lug bolts so as to give clearance between valve flange and expansion-piece flange, to facilitate installation or removal of the valve.

Operating Mechanism

The vertical drive-shaft through which the valve is operated extends through babbitted wall brackets to an operating stand, as shown in Fig. 3, at the gate-chamber floor level. Power is supplied by an electric motor, specifications for which called for "a 7½-hp., 120-volt, 650-r.p.m., multipolar, compound-wound, totally inclosed, direct-current motor, complete." Detail motor specifications covering materials, construction, efficiency, temperature rise, etc., were also furnished. Speed reductions in the ratio of 103 to 1 are obtained by means of a sprocket-chain drive and worm gearing. A chain drive of the silent-running high-speed type was specified, with cut steel sprockets. The worm gearing is of the Hindley type, so machined that at least three teeth will always be in contact. The worm is of mild steel and the wheel of Cramps No. 2 bronze gear metal. A spherical thrust or step bearing sustains the weight of the vertical drive shaft. This bearing and the worm gearing are provided with oil baths, the oil being circulated by means of a sprocket-driven pump.

Automatic Motor Control.—The motor control is so designed that by throwing a five-pole switch into the "open" or "closed" position, when it is desired to open or close the valve, the driving motor will be automatically thrown across the line and its starting resistance thrown out in proper sequence through contactors whose operation is successively controlled by a series of relays operated by the armature current, until such time as the motor is in full operation with its armature directly across the line.

The movement of the valve plug is accompanied by a corresponding movement of a limit switch consisting essentially of a traveling nut driven by a screw which is connected by chain drive to the main drive-shaft of the valve, so that as the latter revolves, the nut moves along the screw. When it reaches a point in its travel corresponding to a point in the valve-plug travel where the plug is within about 1 in. of its full-open or full-closed position, the nut engages a moving contact placed in the control circuit of the motor. This automatically throws into the armature circuit of the motor a sufficient quantity of resistance to reduce the torque of the motor to full-load torque, or slightly below. This reduces the speed of the motor so that the last inch of travel of the valve is at greatly reduced speed.

As the valve reaches the fully opened or closed position, the limit-switch nut engages a second moving contact which closes the overload release coil of the controller and automatically disconnects the motor from the line. The point of engagement of the limit-switch nut with each of its moving contacts is adjustable so that the point of slowing down and the point of stopping the motor can be altered to suit working conditions and the amount of resistance in the armature circuit is also adjustable. The limit-switch nut carries an indicating arrow which marks on a properly graduated plate the position of its valve, both as regards inches of travel and square feet of waterway area.

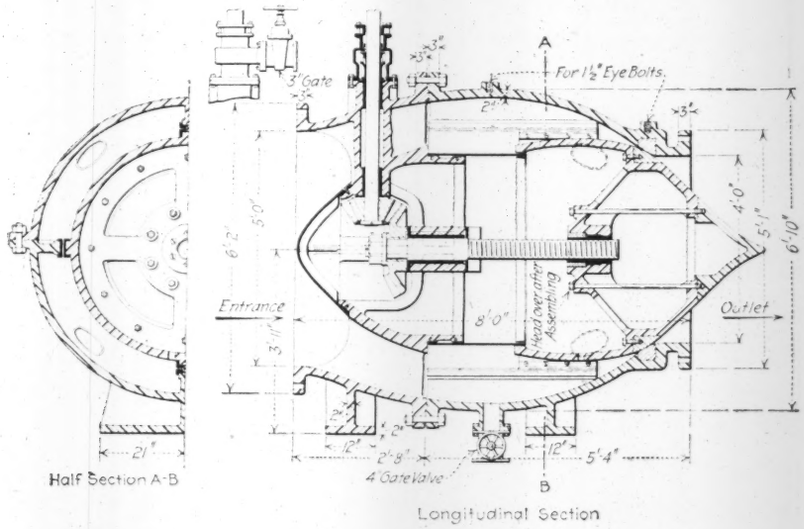


Fig. 2. Sectional Elevations of 48-in. Controlling Valve

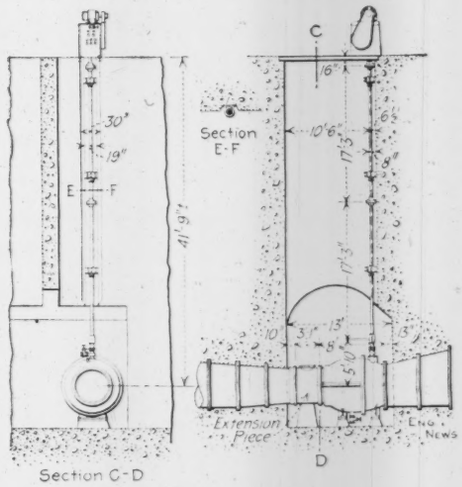


Fig. 3. Controlling Valve in Place in Gate Chamber

It was deemed advisable to mechanically safeguard possible failure of the automatic electrical control to properly operate when the plug reaches its extreme of travel in either direction. For this purpose the motor pinion is provided with a friction device, practically a clutch, which will be adjusted so as to transmit not more than 1¼ times the full-load motor torque.

Materials

The materials entering into the manufacture of these valves were required to meet the following specifications, which gave first-class materials without hardship to the manufacturers:

Cast Iron—All iron castings shall be smooth, free from serious defects and well cleaned. The quality of iron shall be such as will make strong, tough, even-grained castings, but sufficiently soft for satisfactory machining. Transverse test pieces 26 in. long by 2 in. wide and 1 in. thick, when placed flatwise upon supports 24 in. apart and loaded in the center, shall support a load of 2200 lb. and show a deflection of not less than 0.35 in. without showing signs of failure.

Steel Castings—Steel castings shall be made by the openhearth, crucible or bessemer process, and shall be properly annealed. Castings shall not contain more than 0.05% of phosphorus or of sulphur. Tensile strength shall be not less than 60,000 lb. per sq.in., with an elastic limit of not less than 27,000 lb. per sq.in. Elongation shall be not less than 22%, with a contraction of area of not less than 30%. A specimen 1x1½-in. shall bend flatwise, when cold, around a diameter of 1 in. through an angle of 120° without fracture on the outside of the bent portion. Castings shall be suspended and hammered all over in the presence of the engineer, and any serious defects which appear after such treatment shall be cause for rejection. Castings shall be true to pattern and free from serious flaws or shrinkage cracks. Bearing surfaces shall be solid, and no porosity will be allowed in places where the resistance and value of the casting for the purpose intended will be affected thereby.

Bronze Castings—Bronze castings shall conform to the following requirements:

Class A. Copper, 87% to 89%; tin, 11% to 9%; zinc, remainder. Tensile strength not less than 30,000 lb. per sq.in.

Class B. Copper, 82% to 84%; tin, 14.5% to 12.5%; zinc, remainder. Tensile strength not less than 30,000 lb. per sq.in.

All bronze castings shall be made of new metal, shall be free from objectionable imperfections and shall conform accurately to patterns. Specimen bars cast from the same heat, or coupons if so required, will be broken to determine the tensile strength and to ascertain the uniformity of the grain of the metal. When the castings are being machined, if the metal shows signs of imperfect mixing, they shall be rejected.

Plugging Castings—Patching or plugging of castings will not be allowed except for minor defects and then only when approved.

Mild Steel—Mild steel shall contain not more than 0.05% of phosphorus or of sulphur. Test specimens shall have a tensile strength of not less than 58,000 lb. per sq.in., with an elastic limit of not less than 29,000 lb. per sq.in., and an elongation of 28%. A specimen 1½ in. wide by ½ in. thick shall bend when cold 180° around a diameter of ½ in. without fracture on outside of bent portion.

Wrought Iron—Wrought iron shall be made by the puddling process or rolled from fagots or piles made from wrought-iron scrap, alone or with muck bar added. It shall have a tensile strength of not less than 50,000 lb. per sq.in. and an elastic limit of 25,000 lb. per sq.in. with an elongation of 25%.

Tobin Bronze—The tensile strength of Tobin bronze in rolled round bars up to and including 1½-in. diameter, shall be 60,000 lb. per sq.in.; up to and including 3-in. diameter, 55,000 lb. per sq.in.; above 3-in. diameter, 50,000 lb. per sq.in. The elastic limit shall be not less than one-half the tensile strength with an elongation of not less than 20%.

Manganese Bronze—All manganese bronze shall be equal to Spare's or Parsons' manganese bronze and shall have a tensile strength of not less than 65,000 lb. per sq.in., an elastic limit of 45% of the ultimate tensile strength, and an elongation of not less than 25%.

Brass Rivet Rod—The tensile strength of brass rivet rods shall be not less than 55,000 lb. per sq.in. The elastic limit shall be not less than 30,000 lb. per sq.in. with an elongation of 20%.

Babbitt Metal—Babbitt metal shall be made of the following: 3.7% of the best refined copper; 88.8% of Banca tin, and 7.5% of antimony. The materials shall be well fluxed with borax and resin in mixing. One chemical analysis shall be made from every 100-lb. lot, or less.

Gaskets—All gaskets shall be made of the best quality 10-oz. soft corrugated Lake copper 99.5% pure. All circular gaskets under 40 in. inside diameter and all strip gaskets shall be without joints.

General Tests—Test specimens and samples of metals, or any other material, shall be prepared ready for testing as directed at any time during the making or working and supplied in the number, finish and size required. The contractor shall furnish the use of testing machines and all reasonable facilities and assistance for the work of inspection. The engineer may make such tests, either physical or chemical, as he deems necessary to determine the quality of any material.

Standard Test Pieces—The standard test piece for measurements of tensile strength and elongation shall be ½ in. in diameter, and 2 in. long between shoulders.

The body, or shell, plug and expansion piece are steel castings and are sectionalized where necessary for convenience in handling and machining. The body parts are bolted together with steel bolts provided with "Class A" bronze nuts, tight joints being made by means of corrugated copper gaskets between flanges. A sufficient number of fitted bolts of Tobin bronze are provided to secure and maintain alignment of the parts. The seat and plug rings are of "Class A" bronze, and the guides and guide shoes are of "Class B" bronze. Finish cuts were taken over these rings, guides and guide shoes after bolting or screwing in place. The screw stem is of Tobin bronze and the bevel gears of manganese bronze. "Class B" was specified for stem and drive-shaft bronze bushings. The vertical drive shaft is of steel except the lower section in the valve itself, and this is of Tobin bronze.

The assembled weight of valve with plug was 31,000 lb. The heaviest single casting was a spider or entrance casting, which weighed 13,200 lb.

Each valve was subjected to two hydrostatic tests in the shop. The first test was made with the valve wide open, with blind flanges bolted to the entrance and discharge openings. The second test was made with the valve closed and the blind flange on the discharge opening removed. In both tests a pressure of 100 lb. per sq.in. was applied for a period of 30 min., during which all castings and joints were required to be watertight, with no leakage through the seat.

After testing, the valves were painted inside and out with two coats of a black varnish composed of pure Trinidad asphaltum and linseed oil.

Engineers and Contractors

A contract for four controlling valves complete with operating mechanisms and expansion pieces was let to the Ogden Iron & Steel Co., of New York. The steel castings were made by the Midvale Steel Co. The machine work was done by the Watson-Stillman Co., of New York.

The valves, operating mechanisms and control were designed and built under the supervision of J. Waldo Smith, chief engineer, New York Board of Water Supply; Alfred D. Flinn, department engineer, and Horace Carpenter, mechanical engineer, in consultation with Messrs. John R. Freeman and Arthur West.

Forestry Planting by the Water Board, of Baltimore, Md., is proposed. If the plan is carried out, that city will do what a number of others have already done in the same line. For the following statement of what is proposed at Baltimore, we are indebted to Ezra B. Whitman, Water Engineer, of Baltimore:

In regard to the question of foresting the drainage area of the Gunpowder, the Water Board at its last meeting adopted as its policy my suggestion of carrying out a definite scheme of foresting the property along the reservoir on the lands owned by the city. The city will in all probability acquire between 2000 and 3000 acres of land on both sides of the reservoir. A considerable sum of money will be required to buy this property, and it would certainly seem proper to secure some revenue from this land, if it can be done without any detriment to the city water supply. If this land were farmed, in order to secure the best results, it would have to be plowed and manured, and in times of heavy rains a great deal of silt and manurial elements would be washed into the reservoir. This objection precluded the possibility of utilizing the lands owned by the city for farming purposes. I expect to secure the services of expert foresters, establish a nursery, and set out all the farm lands owned by the city in trees, with the view of cutting the timber along scientific lines. This rough timber may be sold directly to purchasers, or it is possible that a municipal sawmill may be established, if the yield from the forest areas will warrant the expense attached to building and operating a sawmill.

Tests of Old Boilers

By Alex M. Gow*

This article, giving the records of tests of three 30-year-old boilers to destruction under hydrostatic pressure, is followed by a second article which presents the results of strain-gage measurements during similar tests on two 27-year-old boilers.

On June 6 and 7, 1911, three horizontal tubular boilers, designated as Nos. 301, 302 and 303, were tested to destruction with hydraulic pressure at Ishpeming, Mich. The boilers were owned by the Oliver Iron Mining Co., and had been in operation for about 30 years at No. 1 Hard Ore Boiler House, Lake Superior Mines. The boilers had been condemned on account of their age by the Hartford Steam Boiler Inspection & Insurance Co., as an unsafe risk, although they showed no signs of deterioration from their 30 years' service—there being no evidence of pitting or corrosion.

Inasmuch as it will probably be necessary to maintain a boiler plant for the next 20 years at the location where these boilers have been, it was decided to install new boilers and test the old ones to destruction to determine whether or not they were unfit for service, and whether any deterioration of any kind had taken place which was not in evidence from an external and internal inspection.

*Assistant Chief Engineer, Oliver Iron Mining Co., Wolvin Bldg., Duluth, Minn.

There were present at the test, representing the Hartford Steam Boiler Inspection & Insurance Co., J. T. Coleman, assistant chief inspector, and Charles J. Enger and George M. Ross, field inspectors. The Oliver Iron Mining Co. was represented by W. H. Johnston, general superintendent; F. E. Keese, superintendent; A. M. Gow, assistant chief engineer, and C. M. Murphy, master mechanic. James Clancy, formerly master mechanic of the Oliver Iron Mining Co., who had charge of these boilers for 30 years, was also present.

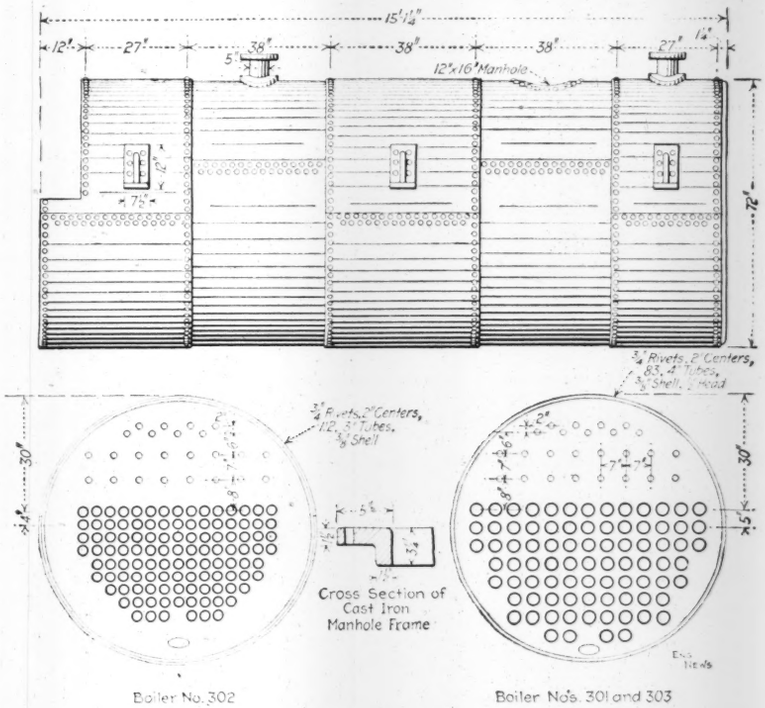


FIG. 1. DRAWING SHOWING CONSTRUCTION OF 30-YEAR OLD BOILERS TESTED AT ISHPEMING, MICH.

The three boilers were identical in construction with the exception that boiler 302 contained 112 3-in. tubes, while boilers 301 and 303 each contained 83 4-in. tubes. The accompanying drawing, Fig. 1, shows the construction of the boilers. It will be observed that each boiler consists of five courses of ⅜-in. sheets, double lap-riveted with ¾-in. rivets, spaced 2 in. c. to c.

Pressure was obtained from a hand pump capable of producing a pressure of 300 lb., and, in addition, the pump of a hydraulic wheel-press was connected to the water line for additional pressure, as required.

To determine the expansion of the shell, a steel tape was passed around the boiler and the movement of the tape was observed to determine the increase in circumference of the shell. Attempts were also made to determine the diametrical expansion with a micrometer gage set against the side of the boiler, but the observations on this gage were not satisfactory. The measurements upon the steel tape, however, were fairly accurate.

BOILER NO. 302

This boiler was built about 1877 by Kendall & Roberts, of Boston. The sheets bore the brand "Bay State Homo." The following log of the test, made June 6, 1911, gives in detail the behavior of the boiler under the successive pressures to which it was subjected:

TABLE I

LOG OF TEST, BOILER NO. 302

Time	Pressure, lb. per sq.in.	Observations
10:12		
:14	60	
:15	93	
:18	100	
:18½	125	1/16-in. elongation in circumference
:20	140	
:20¼	170	
:21	180	Seams weeping slightly
:21½	195	
:22	200	5/32-in. elongation in circumference
:22½	210	
:24½	220	
:25	230	3/16-in. elongation in circumf rence
:25¼	240	All longitudinal seams leaking
:27½	250	
:28	260	
:28¼	275	Manhole frame broken

At 275 lb. pressure, the cast-iron manhole frame broke in two with a loud report and the sheets were ruptured, as shown in Fig. 2. At the time of the rupture, the steel tape showed that the circumference of the boiler had elongated approximately 3/16 in. After the rupture the tape resumed its initial position, indicating that at 275 lb. pressure the shell had taken no permanent set. While there had been some leaking of longitudinal seams, there was no evidence of serious distress at any part of the boiler. The heads showed no sign of bulging and tube ends remained tight.

Test pieces cut from the shell immediately over the fire showed an average tensile strength of 60,460 lb., with 22.5% elongation, 53.7% reduction in area and an elastic limit of 36,690 lb. The analysis of this sheet showed: Carbon, 0.13; sulphur, 0.026; phosphorus, 0.097; manganese, 0.27. The test pieces were cut

both transversely and longitudinally of the sheet, but it was impossible to tell from the way the test pieces broke in which way the sheet had been rolled. It is very evident that there had been no deterioration of the steel in this sheet. Test pieces were also taken from a sheet at the top of the boiler, where it was not subjected to the action of the fire. These test pieces gave an average of 70,145 lb. tensile strength, with an elongation of 20.12%, an elastic limit of 39,060 lb., and a reduction of area of 47.05%.

In addition to the test pieces cut from the sheets as above mentioned, a section was taken out of the longitudinal seam. Upon being pulled in the testing machine, the joint gave an efficiency of 60% of the plate, breaking through the rivet holes. This seam showed no evidence whatever of deterioration and was as good as the day it was laid up. Subjected to cold

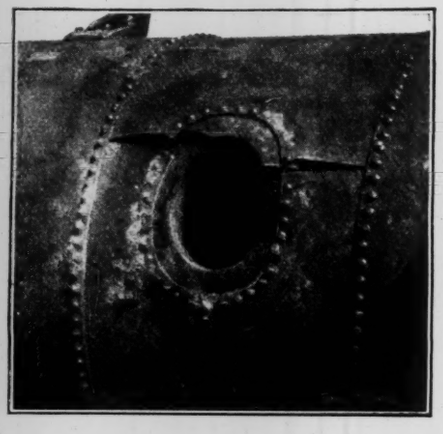


FIG. 2. PHOTOGRAPH SHOWING MANHOLE FRAME OF BOILER 302 AFTER FAILURE AT 275-LB. PRESSURE

bending tests, the test pieces from the sheets above the fire bent to 180°, flat, without fracture.

BOILER NO. 303

Boiler 303 was built about 1879 by Kendall & Roberts, of Boston. The sheets bore the inscription "Nashua Iron & Steel Co., Nashua, N. H.," and an encircled Indian head, and were stamped "cast steel, 60,000 lbs." Inasmuch as this boiler was identical in construction with boiler 302, which had developed its weak point in the manhole frame, and as it was desired to put a greater pressure on the boiler than the manhole could stand, it was decided to remove the frame and put on a 5/8-in. patch, secured by patch bolts, in place of the cast-iron frame.

On the morning of June 7, pressure was applied to the boiler in the same manner as to boiler 302 the day before. The log shown in Table II gives the observations in detail:

TABLE II

LOG OF TEST, BOILER NO. 303

Time	Pressure, lb. per sq.in.	Observation
10:00	15	
:01¼	20	
:01½	30	
:03	90	
:03¼	110	1/16-in. elongation in circumference
:05	150	
:05¼	160	Seams begin to weep
:06	170	
:06½	180	3/32-in. elongation in circumference
:07½	220	
:08	225	⅛-in. elongation in circumference
:08½	240	One girth seam leaking.
:09½	250	5/32-in. elongation in circumference
:11	270	
:11½	275	1/16-in. elongation in circumference
:12½	280	
:13	285	3/32-in. elongation in circumference; tubes beginning to leak
:15	295	
:16½	297	Could obtain no more pressure by hand pump; pressure let down and hydraulic pump cut in. Boiler resumed its normal diameter; no permanent set
:25	175	
:26	195	1/16-in. elongation in circumference
:27½	255	
:28½	275	
:28¾	295	
:29	300	3/32-in. elongation in circumference
:30	300	Seams leaking badly and some leaking at the ends. Stopped pumping to calk one patch bolt and tighten one plug.
:34	...	Pressure let down
:45	...	Started pumps again
:46	125	
:46½	145	Stopped pump to roll one tube
:53	145	
:55	160	3/32-in. increase in circumference
:55½	180	
:55¾	210	1/16-in. increase in circumference
:56	230	
:56½	250	3/32-in. increase in circumference
:56¾	270	
:57	...	⅛-in. increase in circumference
:57½	285	
:57½	295	Tube leaking. Head also shows signs of distress.
:58	300	Beading on tubes is sprung
:59½	295	3/32-in. increase in circumference
11:00	300	13 patch bolts sheared

At 300 lb. pressure the patch and one plug began leaking so badly that the pumps could not gain, and it was necessary to reduce the pressure and calk the leaks. At 10:45 the pressure was again applied and upon obtaining 300 lb., there was noticeable distress on one head, with leaking of tubes and springing of the beading. The steel tape indicated that the boiler was increasing in diameter. The leaks were of such an amount that the two pumps were not able to gain over 300 lb. pressure, and at this pressure 13 of the patch bolts sheared. The manhole sheet expanded approximately ½ in. with no rupture. It being impossible to replace the patch, and the head having shown evident distress, no further attempt was made upon this boiler to burst the longitudinal seams. The steel tape showed that the boiler had expanded about ¼ in., and it did not resume its normal diameter.

Test pieces cut from the sheet immediately over the fire on this boiler showed a tensile strength of 60,186 lb.; elastic limit, 38,280 lb.; elongation, 21.5%, with 54.52% reduction of area. Analysis of the steel gave: Carbon, 0.17; sulphur, 0.023; phosphorus, 0.097; manganese, 0.29. Test pieces cut from the sheet at the top of the boiler showed a tensile strength of 56,400 lb.; elastic limit of 37,230 lb., and an elongation of 27.25%, with 64.88% reduction of area. Analysis of this steel showed: Carbon, 0.25; sulphur, 0.021; phosphorus, 0.092; manganese, 0.37.

BOILER NO. 301

Boiler 301 was identical in construction with boiler 303. It was purchased at the same time and the sheets bore the same brand. It was tested in the same manner, and the log of the tests in Table III shows the observations:

FIG. 3. A 6-IN. DISK CUT FROM SHELL OF BOILER 302, ABOVE FIRE JUST FORWARD OF BRIDGEWALL

TABLE III

LOG OF TEST, BOILER NO. 301, JUNE 7, 1911

Time	Pressure, lb. per sq.in.	Observation
11:15	...	Pump started
:15½	55	
:17	85	
:17½	100	
:18½	150	1/16-in. increase in circumference
:20	155	
:20½	180	Seams weeping
:21	205	Flues leaking a little
:21½	225	
:22	235	Leaking at manhole
:22½	250	3/32-in. increase in circumference
:23½	255	
:24	260	Manhole broke; ⅛-in. increase in circumference

At 260 lb. pressure the manhole casting broke in identically the same manner as that upon boiler 302, first tested. The steel tape, however, showed that the boiler had taken a permanent set of ⅛-in. elongation in the circumference, probably due to slight movement of the longitudinal seams, which showed signs of distress.

Test pieces taken from a sheet immediately over the fire showed a tensile

strength of 60,780 lb.; elastic limit, 33,100 lb.; elongation, 26.5%; reduction of area, 61.62%. Analysis as follows: Carbon, 0.13; sulphur, 0.022; phosphorus, 0.105; manganese, 0.20. Test pieces taken from the top of the shell, not subjected to the fire, showed a tensile strength of 61,680 lb.; elastic limit of 38,820 lb.; elongation, 19.75%, and a reduction in area of 50.80%. Analysis as follows: Carbon, 0.18; sulphur, 0.022; phosphorus, 0.085; manganese, 0.28.

The tests for tensile strength and the chemical analyses were made at the works of the Illinois Steel Co., South Chicago, through the courtesy of P. E. Carhart, inspecting engineer. Twelve test pieces were measured with a micrometer and showed a maximum thickness of sheet of 0.380 in.; minimum thickness, 0.364 in.; average, 0.373 in. This variation in thickness is no greater than would be expected in nominal 3/8-in. boiler plate, and showed that there had been no appreciable reduction of thickness by reason of corrosion on the surface of the plates.

Fig. 3 is from a photograph of a piece 6 in. in diameter cut from the shell immediately over the fire and just forward of the bridge-wall on boiler 302. The brand is as clear and well defined as the day it was put on the sheet, and shows the "Indian head" very distinctly. Micrometer measurements of this piece of steel show a thickness of 0.366 in.

The boilers had been originally built to carry 100 lb. pressure, but inasmuch as, allowing the longitudinal seams an efficiency of 60% of the plate, this would give a safety factor of but 3.75, the working pressure had been fixed at 80 lb., giving a safety factor of 4.70. It is evident that the weak point of each boiler was the cast-iron manhole ring. Boiler 301 broke at this point at a pressure of 260 lb. With the pressure of 80 lb., the safety factor at this point was, therefore, but 3.25.

Had this cast-iron manhole ring broken in service it is not probable that an explosion would have resulted. Fig. 2 shows a ruptured sheet from boiler 302. This rupture occurred when the manhole ring broke at a pressure of 275 lb. When the manhole ring on boiler 301 broke in identically the same manner, at a pressure of 260 lb., the sheet was not ruptured. Furthermore, when the patch bolts sheared at a pressure of 300 lb. on boiler 303, the sheet was not ruptured. It is fair, then, to assume that had a manhole ring let go in service at a pressure of from 80 to 100 lb., no rupture of the sheet or explosion of the boiler would have followed. But upon this point there is room for a difference of opinion.

Summary

It is evident from all the above tests that there had been no deterioration in the quality of the material, and it was such as would pass today for good boiler plate. The one sheet from the top of boiler 302, that had a tensile strength of 70,000 lb., showed slight cracks under the cold-bending test to 180°, flat. The fracture in every case was good and no one of the test pieces showed the slightest indication of lamination or lack of homogeneity.

Taking it all in all, the boilers were as good as the day they were made. They were made from excellent material. The workmanship was admirable and subject to only one criticism—the rivet holes had not been reamed. With this exception the workmanship could not be improved upon. In no way, shape or form had the boilers deteriorated by the 30 years' service to which they had been subjected. The water furnished them had been of uniformly good quality. They had received excellent care and attention. At times they had been fired very hard, sometimes with wood, sometimes with coal, and at times, a mixture of wood and coal.

It is interesting to note in this connection that the Bay State Iron Works, which made the steel for boiler 302, had, according to a list of rolling mills and steel works, published in 1882, one 6-gross-ton Siemens openhearth steel furnace, with an annual capacity of 2800 net tons of ingots. The Nashua Iron & Steel Co., Nashua, N. H., had one 10-gross-ton Siemens openhearth steel furnace. These furnaces must have been among the earliest Siemens openhearth furnaces built in the United States, and these boilers among the very early ones built from such material.

Strain Measurements of Two Old Boilers under Hydrostatic Pressures*

By James E. Howard†

The object of these tests is to ascertain the condition of the metal of the shell and other parts of two horizontal tubular boilers which had been in use for a term of service of unusual length; and in addition thereto to acquire information on constructive details by means of measured strains.

Measurements of the deformations of engineering structures, whether steam boilers, bridges or buildings, may be expected to develop information of a kind not attainable in the tests of the component parts of those structures. A comparatively new field of inquiry is presented in the tests of structures over the tests of the materials thereof. The effects of combined stresses may readily be studied in this manner.

The boilers were contributed for investigative purposes by the treasurer of the Kendall Manufacturing Co., Providence, R. I., the late Nicholas Sheldon, Esq. They were of early manufacture and from their remarkable history and present condition were of special value for these tests. They were made by the Whittier Machine Company, Boston, Mass., using the "Benzon" brand of steel, and were put into service in March, 1881. They were in continuous service for a period of 27 years, during which time, as Mr. Sheldon wrote, "no repairs were required; in fact, not one cent has been spent upon them."

They were five-course boilers, two sheets to a course, having the following general dimensions:

Diameter	72 in.
Length, over dry sheet	16 ft.
Thickness of shell	3/8 in.
Thickness of heads	1/2 in.
Number of tubes	140
Diameter of tubes	3 in.
Length of tubes	15 ft.
Diameter of dome	2 ft. 6 in.

Longitudinal seams, double-riveted lap joints, 3/4-in. rivets, 2-in. pitch, punched holes, rows 2 1/8 in. apart, rivets staggered.
Girth seam, 3/4-in. rivets, 2 1/8-in. pitch.
Heads stayed, each with 14 braces.
Cast-iron manhole frames and safety-valve nozzle.
Supported by lugs, three on a side.
The feedwater came from the Pawtucket River.

No more simple type of boiler could be chosen than the plain, horizontal, tubular

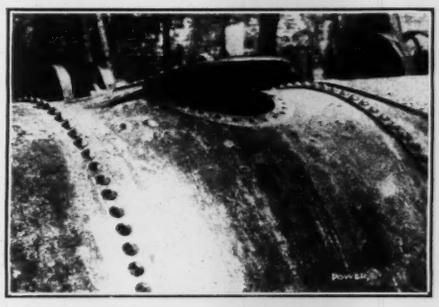


Fig. 1. Manhole Patch Ruptured at 335-lb. Pressure in Test at Providence, R. I., Boiler 4092

boiler of these tests, yet it will be seen from the results that complexity of strains and stresses is found in most parts of the shell. In comparatively few places are tangential strains displayed corresponding in magnitude to those which would be expected in a thin cylindrical shell subjected to a given interior pressure.

Method of Testing

The hydrostatic tests were made at the W. H. Hick's Boiler Works, Providence, R. I. Francis B. Allen, vice-president of the Hartford Steam Boiler Inspection & Insurance Co., assisted and advised with the writer in conducting them. The boilers will be designated by the numbers 4084 and 4092 under which they were carried on the books of the Hartford company. Both boilers were of the same dimensions except at the dry sheets

*Abstract of a paper presented at the December, 1911, meeting of the American Society of Mechanical Engineers.

†Engineer-Physicist, Bureau of Standards, Washington, D. C.

When on their settings, boiler 4084 was on the right, boiler 4092 on the left side.

The tests began with strain measurements upon different parts of the boilers as they were subjected to successive increments of hydrostatic pressures. The results of this portion of the inquiry are now available and herewith presented. Much remains to be done in the other direction of testing, pertaining to the physical properties of the materials.

Ascertaining the deformations by the method of measured strains, locally determined, consists of establishing gaged lengths on different parts of the boiler and then measuring them initially and at intervals as the hydrostatic pressures are successively applied and released. Gaged lengths of 10 in. each were used in the examination of these boilers. Their extremities were defined by small drilled and reamed holes. The holes are about 0.05 in. in diameter by, say, 0.10 in. deep, and reamed to a conical shape. The angle of the reamer is 65°, and the distance across the hole at the surface of the shell sheet about 0.08 in. Such holes carefully made, in metal surfaces, are capable of centering with considerable precision the contact points of the micrometer strain gage. The strain gage is used as a transfer instrument to compare the gaged lengths on the work with a corresponding length on a standard reference bar.

The 10-in. strain-gage used on these tests consists of two principal parts, an outer tube and an inner stem, which are telescopic, working on ball bearings.* Each part carries a conical contact point for centering the instrument on the reference bar and on the work. A screw micrometer measures the length of the instrument when in position. The conical contact points of the strain-gage have an angle of 55°. This difference of 10° between the reamed hole in the boiler shell and the points of the gage secures contact at a short distance below the surface of the shell. Ordinarily the reference holes are safe against accidental injury, due to their position.

As to the degree of precision attained with the strain-gage, in the hands of skilled manipulators and under favorable conditions, such as were experienced with these boilers, it is believed the readings are generally reliable to one ten-thousandth of an inch. This strain corresponds to a stress of 300 lb. per sq.in. on a 10-in. gaged length, using a modulus of elasticity of 30,000,000 lb.

A more comprehensive series of lengths was established on boiler 4092, and the general discussion of the results of the strain measurements will be given in connection with the test of that boiler. Additional tests were carried out, in which the effect of changes in the manner of supporting the boiler was inquired into. It was supported on the four end lugs in one test, and again in another test most of the weight was carried by the middle lugs. In each case there was a modification in the measured strains, although not in a marked degree. At the end of the test the several courses were seen to have been visibly extended in diameter between the girth seams.

The services of P. W. Brunner and J. W. Herrity are acknowledged, whose skill as manipulators is shown by the internal evidence of reliability furnished by the measurements themselves.

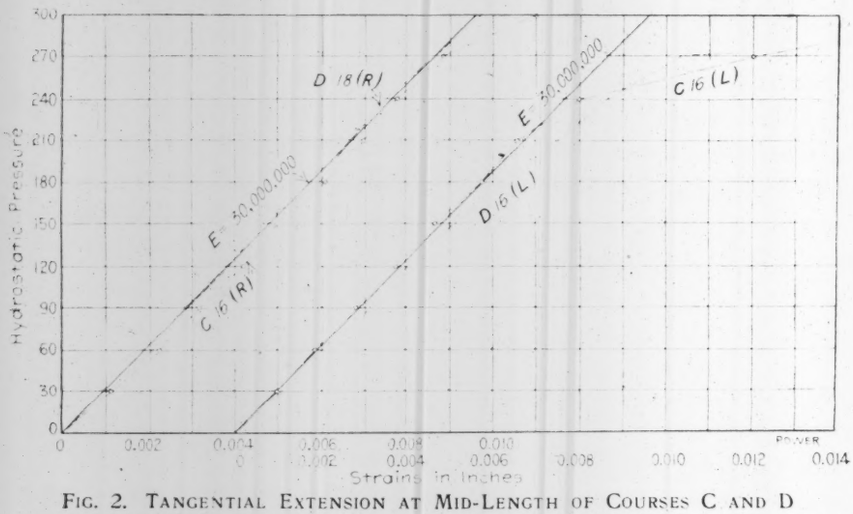


FIG. 2. TANGENTIAL EXTENSION AT MID-LENGTH OF COURSES C AND D
(R, right side of boiler; L, left side. See Figs. 5 to 7 for location of measurements.)

TEST OF BOILER 4084

In the test of No. 4084 greater strains were displayed in the vicinity of the dome and the manhole frame than at other parts of the shell. This resulted, as would clearly be expected, in the early failure of the boiler at those places. Actual rupture of the dome was not accomplished, but leakage along its single-riveted longitudinal seam became so great at 266 lb. pressure that it was necessary to remove the dome and patch the shell in order to reach higher pressures with the pump available. At 270 lb. pressure the cast-iron manhole frame fractured across the middle of its length. Another patch was then put on the shell covering the manhole.

The test was again resumed and at 295

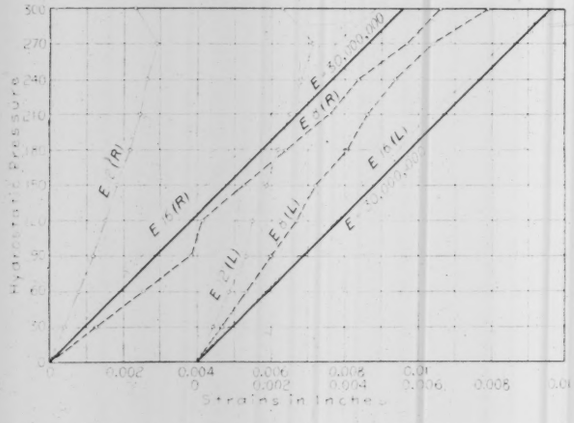


FIG. 3. TANGENTIAL EXTENSION AT MID-LENGTH AND AT GIRTH SEAM OF END COURSE E

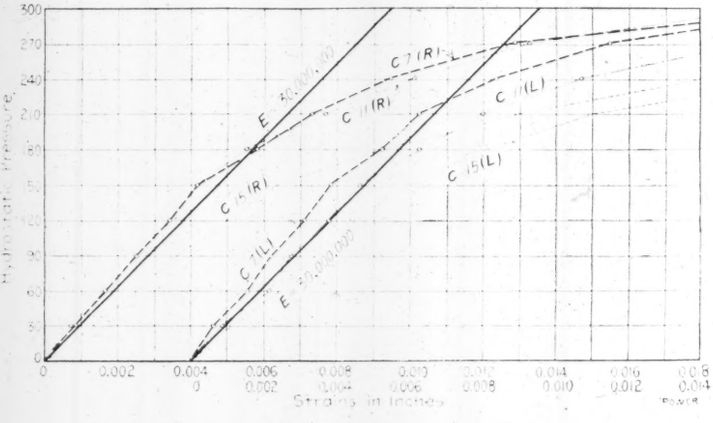


FIG. 4. TANGENTIAL EXTENSION ACROSS LONGITUDINAL SEAMS AT MID-LENGTH AND AT EDGES OF COURSE C

*The Howard strain-gage was described in Engineering News, Mar. 23, 1911, p. 352.—Editor.

lb. pressure the rupture of three braces of the front head occurred. The test was then discontinued and the boiler dismantled.

The strain measurements made in the test of No. 4084 were of the same general order as those subsequently made in the test of the second boiler and the results were, for the most part, quite similar. A feature, however, in the test of the first which was absent or obscure in that of the second was a progressive difference in the extensibility taken across the longitudinal seams of the several courses in passing from the front to the rear end of the boiler.

The tangential extensions of the seams, at the middle of their lengths, were as shown in Table I.

TABLE I. TANGENTIAL EXTENSIONS OF THE SEAMS, BOILER 4084

Pressures	Course*			
	B	C	D	E
210	0.0166	0.0121	0.0099	0.0084
240	0.0241	0.0171	0.0138	0.0121
270	0.0341	0.0241	0.0212	0.0187

*See Figs. 5 to 7 for lettering of courses.

While these seams were not directly exposed to the heated gases over the grate, nevertheless it seems probable that a wider range of thermal conditions prevailed in the vicinity of the seams at the front end over those at the rear end of the boiler. If such was the case it would aid in explaining the greater slip of the forward seams.

Hydrostatic pressures on the exterior surfaces of the tubes necessarily extend them in length. The amount of the extension appears to depend upon their position with reference to their proximity to the shell. Tubes adjacent to the shell extended less than those at the middle of the rows, a restraining influence from the shell appearing to affect the outer ones. The results in Table II were obtained by measuring the tubes over their full length.

TABLE II. EXTENSION OF TUBES, BOILER NO. 4084

Pressures	Third Row		Seventh Row	
	Next shell	Middle of row	Next shell	Middle of row
210	0.0110	0.0162	0.0077	0.0167
240	0.0128	0.0184	0.0086	0.0189
270	0.0142	0.0210	0.0099	0.0210

Practically no leakage occurred about the tubes throughout the test of this boiler. A slight leakage took place at two tubes at 120 lb. pressure, but soon ceased and was not renewed during the remainder of the test. The girth seams remained tight up to 210 lb. pressure, and then showed only small leaks which were not materially increased under the higher pressures. Leakage at the longitudinal seams began at 120 lb. pressure and increased as higher pressures were applied. The leakage became general at these seams with 180 lb. pressure on the boiler, but at this time the slip of the joints had become a pronounced feature of the case, which necessarily disturbed the calking.

Upon removal of the dome, evidence of overstraining was found at its base next the flanged portion. The scale had been disturbed on the inside on the line and in the vicinity of the upper element of the boiler. Near the flange the scale was disturbed in oblique, shearing directions, which changed to longitudinal and then tangential directions a little farther up the dome.

Struts were used under the middle lugs and supported a part of the weight of the boiler during the test. They probably intensified the stresses in the shell in that vicinity. The interior surface of the shell and also the heads were found in good condition.

Test of Boiler 4092

Prior to testing boiler No. 4092, it was stripped of its dome and manhole frame and the shell patched at those places. The heads were strengthened by means of six 1¼-in. braces extending from head to head. The cast-iron safety-valve nozzle was allowed to remain in place, but was eventually replaced by a soft patch, after 300 lb. pressure had been applied and released. The distortion of the shell under the flange of the nozzle caused leaks which it was impracticable to calk.

The interior pressure was then increased from 300 lb. to 335 lb., and at this pressure the rupture of the manhole patch occurred as shown in Fig. 1. Three of the rivets were sheared by the tangential stress of the shell; and this was followed apparently by the fracture of other rivets by tension on the stems, which pulled off the heads and finally tore the shell longitudinally along its upper element. The tear started at a rivet hole of the manhole opening.

The shell was repaired by cutting out a portion of course *C*, across the top of the boiler and putting in a section the full length of the course and about 3 ft. wide, measured on the arc. This new section was double-riveted to the shell at its longitudinal seams. The rivets were ⅞ in. in diameter and had a pitch of 2.87 in. The rows were 1.53 in. apart with rivets staggered. The rivets were, of course, hand driven, and the points were hammered down to conical shape, low in height and with thin edges. In this respect they were less substantial than the points of the original machine-driven rivets of the seams. This weakness was revealed in the test.

At the time of presenting these notes, no higher pressure has been reached than the one of 335 lb. previously mentioned.

The boiler was supported on two wooden shoes sawed to fit the curvature of the shell. The positions of the gaged lengths which were established on the right side of the boiler are shown in Figs. 5 to 7 and practically stand for those on the left side, while additional ones were laid off on the top. Additional gaged lengths were laid off and measured, the results of which confirmed those which will be referred to. There were 165 gaged lengths used in the principal series of observations, on which some 3300 readings were taken.

The chemical composition of the steel in course *C*, was as follows:

Carbon	0.22
Manganese	0.43
Silicon	0.046
Sulphur	0.028
Phosphorus	0.043

The metal from course *C*, the only sheet yet examined, was found to have a laminated structure, as was shown by the appearance of some fractured strips from this course, which were bent while at a blue heat, in order to develop the lamination of the plate in a pronounced manner. The metal drifts well, a ¾-in. diameter punched hole having been drifted cold to 1¼-in. diameter without rupture. It is recalled that this particular brand of steel, at the time of its manufacture, was not infrequently found to possess a decidedly laminated structure. The laminations were not large, nor likely to cause blisters in the boiler, but they were in places quite numerous.

Tangential Strains—The general results of the strain measurements have been plotted on a series of ten diagrams, three of which are shown in Figs. 2 to 4. For the purpose of furnishing a convenient basis of comparison, in judging the behavior of the boiler at different parts and under different pressures, heavy lines have been drawn on each diagram which indicate strains corresponding to those which would be displayed by the sheets under direct tensile stresses, using a modulus of elasticity of 30,000,000 lb. per sq.in. Plotted curves, which are steeper than the modulus of elasticity reference line, indicate places on the boiler having greater rigidity than normal to the plain sheets; while flatter curves indicate greater extensibility than pertains to the plain metal.

Tangential rigidity above the normal was displayed in the vicinity of the girth seams, while the gaged lengths taken across the longitudinal seams at the middle of the length of the courses showed a much lower degree of rigidity than common to the plain sheet. Zones of greater extension than normal were also found in the vicinity of the manhole and dome.

Flattening of the curves representing the solid sheets necessarily accompanied those pressures which caused a tensile stress on the shell in excess of its elastic limit.

Table III shows the computed stresses on the shell sheets, considering only tangential stresses as acting, and the strains which should be developed on a gaged length of 10 in., using a modulus of elasticity of 30,000,000 lb., the interior diameter of the boiler being 72 in.

TABLE III. COMPUTED STRESSES ON THE SHELL SHEETS, BOILER NO. 4092

Boiler pressure, lb. per sq.in	Stress on ⅝-in. shell, lb. per sq.in.	Strain on gaged length of 10 in.
30	2,880	0.0010
60	5,760	0.0019
90	8,640	0.0029
120	11,520	0.0038
150	14,400	0.0048
180	17,280	0.0058
210	20,160	0.0067
240	23,040	0.0077
270	25,920	0.0086
300	28,800	0.0096

Referring now to the plotted results, Fig. 2 shows the tangential extensions of sheets *C* and *D* on the right and left sides of the boiler, respectively, taken at the middle of the lengths of the courses. Gaged length *D*-18, on the right side of the boiler, was located above the longitudinal seam, while *C*-16, on the right side, was located below the longitudinal seam.

The tangential extensions of each of these gaged lengths closely follow the modulus of elasticity comparison curve. The departure of *D*-18 from this line does not exceed 0.0002 in. at any pressure, and coincides with it at several pressures. The extensions displayed by the gaged lengths on the opposite side of the boiler agreed fairly well with the modulus of elasticity reference line also, but not so closely as the results found on the right side, while rapid extension took place earlier, by one increment of pressure, than on the right side. So close a correspondence between the measured and the computed strains as shown on this diagram did not, however, characterize many places on the shell. Commonly there were modifying influences which disturbed the normal display of elastic extensions of the metal.

The tangential strains near the girth seams, *D*-5 and *D*-9, were less than at the middle of the course. In general this behavior was shown in the other courses, but an exception was found on the left side of the boiler in course *B* where substantially the same rigidity was displayed at the middle as at the edges of the course. However, on the left side of course *D*, the extension of *D*-16 taken at the middle of the course was greater than at *D*-8 and *D*-12, representing the edges.

There is a marked difference in the tangential extension of the two edges of the end courses of the boiler, due to the influence of the heads in supporting the shells. Fig. 3 shows the greater rigidity found at the gaged lengths *E*-12, which are taken nearly over the rear head, than at the other places measured on this course.

In regard to the top of the boiler there were many disturbing factors present, as indicated by Figs. 8 to 10. The first course is a short one with the front head to stiffen one edge. Then came the dome in the original construction on course *B*, which was patched and the patch double-riveted, using the rivet holes that were made for securing the flange of the dome to the shell. Course *C* had the manhole patch, a single-riveted one using the holes made for securing the manhole frame to the shell. In course *D* was the feedwater connection which probably did not have much influence on the behavior of this course while under pressure. Course *E* had the cast-iron safety-valve nozzle riveted to it, which did seem to have an influence on the tangential extension of the steel, permitting greater extension than normal.

The extension of course *A* at the edge over the front head was less than at the opposite edge. Gaged lengths *B*-52 and

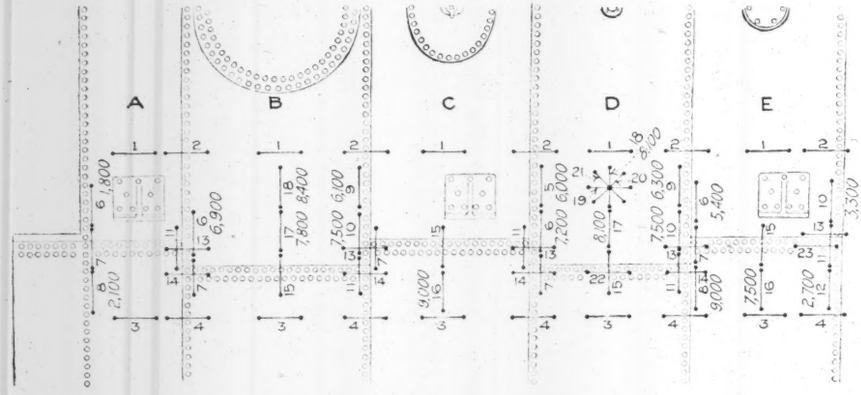


FIG 5. AT 90-LB. PRESSURE
(Normal, computed stress, 8,640 lb. per sq.in.)

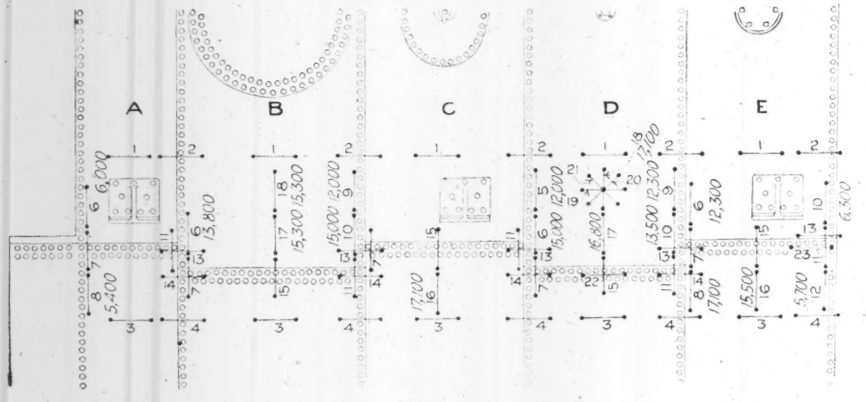


FIG. 6. AT 180-LB. PRESSURE
(Normal, computed stress, 17,280 lb. per sq.in.)

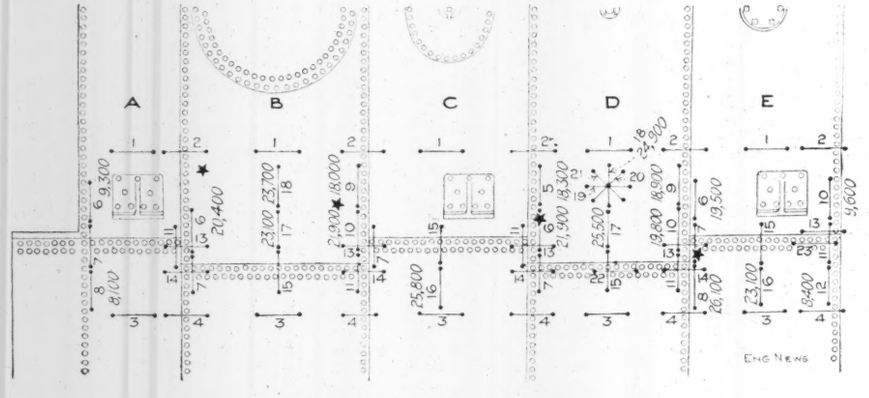


FIG. 7. AT 270-LB. PRESSURE
(Normal, computed stress, 25,920 lb. per sq.in. Gage lengths on which decided permanent sets occurred are indicated by stars.)

FIGS. 5, 6 AND 7. TANGENTIAL STRESSES, LB. PER SQ.IN., ON RIGHT SIDE OF BOILER 4092

(Stresses shown were computed from resiliences found by subtracting permanent set from measured extensions.)

B-57 showed the influence of the overlapping metal of the patch, as well as that of the girth seams. The extension at these two places was less than normal. At the side of the manhole patch, *C*-58, there was found diminished rigidity in the shell. The weakness of this single-riveted patch was apparent in the measurements from the earliest pressures which were applied to the boiler. Conditions about the safety-valve nozzle did not seem fully to compensate for the opening in the shell, as shown by the extensions on gaged lengths *E*-63 and *E*-64.

Referring next to the behavior of the shell at the seams, Fig. 3 shows two groups of curves of three lines each which represent the tangential extensions on gaged lengths established on course *C* taken across the longitudinal seam at the middle and at the edges of the course. Curves *C*-7 and *C*-11, representing the extension at the edges of the course on the right side of the boiler, coincide in places and show but slight divergence where they depart most from the same line; that is, they indicate that uniform behavior was displayed at the opposite edges of this course. Both deflect rapidly under pressures above 150 lb. per sq.in., corresponding to a tensile stress of 14,400 lb. per sq.in. on the solid sheet.

At the middle of the length of the course, curve *C*-15 showed an increase in the rate of extension at the above-mentioned pressure, and for each succeeding pressure a greater extension than that witnessed at the edges. Necessarily, variations in the tangential extensions at different parts of the length of a seam would cause variations in the stresses of the solid metal of the shell in those localities. In the case of a three-course boiler with one sheet to a course, as found in current construction, it would seem, therefore, that a double-riveted lap joint might occasion an excessive stress in the solid sheet abreast the end of the seam, under certain pressures. In the present test the longitudinal seams, being only three rivet pitches apart, furnish a line from front to rear of the boiler across which the extensions are greater than those which are displayed by the solid sheets.

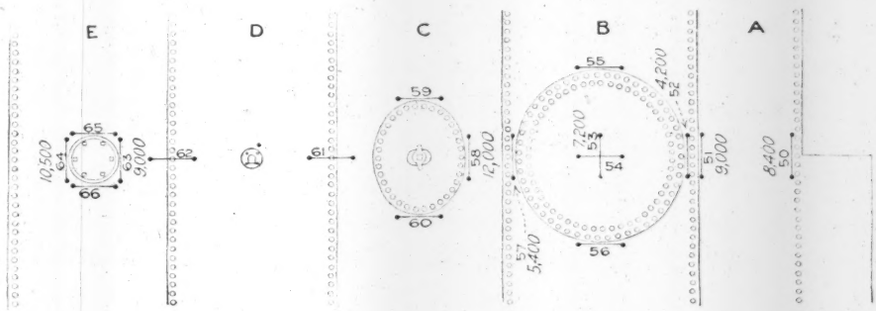


FIG. 8. AT 90-LB. PRESSURE
(Normal stress, 8640 lb. per sq.in.)

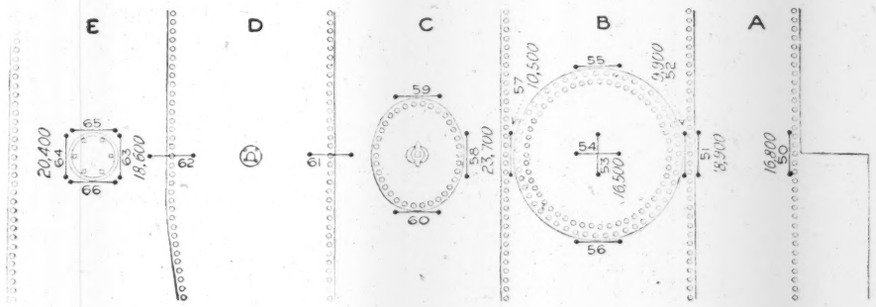


FIG. 9. AT 180-LB. PRESSURE
(Normal stress, 17,280 lb. per sq.in.)

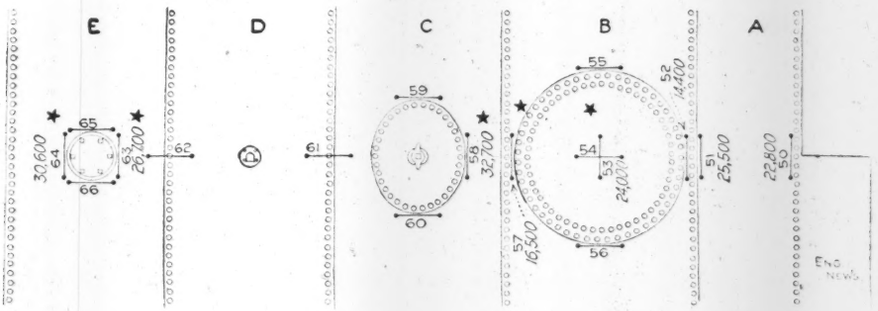


FIG. 10. AT 270-LB. PRESSURE
(Normal stress, 25,920 lb. per sq.in.)

FIGS. 8, 9 AND 10. TANGENTIAL STRESSES, LB. PER SQ.IN., ON TOP OF BOILER 4092
(Stresses shown computed from resiliences, as in Figs. 5 to 7.)

The strains in the narrow end course *A* were relatively such as would be expected under the conditions present in this part of the boiler. In course *E*, at the rear end of the boiler, the behavior of the shell was found to be similar to that at the front end.

Notwithstanding the fact that the results appear consistent and the relations between the different parts of the boiler harmonious, attention is attracted by the variableness of the strains as they are found developed, according to the position of the measured lengths. The degree of variability witnessed in this type of boiler, which is certainly one of plain form, is such as to excite speculative interest in more complicated types.

Curves were plotted for the purpose of showing the elastic extensions only, or their equivalent, the resilience of the shell, taken across the longitudinal seam of course *D*, right side. Greater resilience was noted for gaged length *D*-15, which was located across the longitudinal seam at the middle of its length, than the amount called for by the modulus of elasticity curve. This might be taken to indicate an intensity of stress above the normal in the shell in that vicinity, or it may mean that bending and shearing stresses at the seam in addition to tensile stresses on the sheets modified the results.

LONGITUDINAL STRAINS — The strain measurements thus far described were those which were observed on tangential gaged lengths. In addition to this as indicated in the diagrams, Figs. 5 to 10, there were longitudinal gaged lengths laid off on the shell and measured.

In a plain cylindrical shell the tangential extension of the metal would necessarily be attended with a definite amount of longitudinal contraction, eliminating the effect of pressures on the head. The conditions, however, which are present in steam-boiler construction will generally prevent realizing the longitudinal strains which would be looked for in a plain sheet. In the present test there were parts of the boiler nearly free from longi-

tudinal strains, while in other places the strains were reversed, and longitudinal extension shown instead of longitudinal contraction.

In order to determine whether the action immediately at the girth seams was represented by the 10-in. gaged lengths which spanned them symmetrically, other gaged lengths were established on the shell not indicated on the diagrams herewith presented. These were in pairs, one being wholly on the solid sheet, the other just stepping on to the adjacent course. The observations on these gaged lengths led to the same results, however, as found on those which symmetrically spanned the seam.

The results of these observations showed that along the lower quarter of the boiler the longitudinal strains were contractions; while along the upper quarter they were in part contractions, and in part extensions. At 270 lb. pressure, the lower part of the shell contracted longitudinally, notwithstanding the fact that the tubes were extended by reason of the exterior pressures to which they were subjected. This behavior calls for bending at the flanges of the heads to compensate for the difference in direction of these movements.

The six through braces would relieve the shell of a portion of the longitudinal tension coming from the heads in the upper half of the boiler, but longitudinal gaged lengths on the upper part of the shell showed diminished contractions over those observed on the lower portion, or displayed strains of extension. On the very top of the boiler the strains were extensions of a pronounced order.

It was found on diagonal gaged lengths, laid off on courses *B* and *D*, upper quarter of the boiler, that greater extensions were displayed on the converging diagonals over those of diverging directions. The converging diagonals, at 270 lb. pressure, extended 0.0047 in. and 0.0042 in., respectively, against 0.0036 in. and 0.0028 in. displayed on the diverging gaged lengths.

The location of the diagonal gaged lengths on course *D* are shown in Fig. 5 and similar lengths were laid off on course *B*. The range and variability of the strains for each pressure, 90, 180 and 270 lb., respectively, were very pronounced.

The results presented in Figs. 2, 3 and 4 include both the elastic strains and the permanent sets of the different measured lengths. The permanent sets have been subtracted from the extensions and the stresses corresponding to these resiliences computed, and the results entered on another series of diagrams, Figs. 5 to 10, inclusive. These results show the tangential stresses in pounds per square inch which were found in different parts of the solid sheets of the shell, when the boiler was subjected to pressures of 90, 180 and 270 lb., respectively.

Conclusions

In looking over the results the usual influence of longitudinal seams, such as were used in this boiler, in intensifying the tangential stresses in the adjacent solid sheets, may be pointed out. The excessive stress at the side of the single-riveted manhole patch is clearly shown in the results. The high stresses at the sides of the safety-valve nozzle under the maximum pressure will also be noted.

While the results are consistent, nevertheless as an engineering structure the distribution of stresses exhibits a range far beyond that which is expected in other classes of constructive work. The type of boiler being one of the simplest, the extension of this method of test to other types would seem desirable. Such tests might assist in establishing satisfactory rules for steam-boiler construction and might reasonably be expected to aid in the framing of regulations governing allowable pressures.

Shipbuilding in the United States in 1909 and 1904

Shipbuilding in the United States in 1909 and 1904 is the subject of a preliminary statement of the U. S. Census Bureau summarized in the accompanying table, which shows the operation of concerns building steel and wood, steam, sail and unrigged vessels, yachts, motor boats, row boats, canoes, masts, spars, oars and rigging. The operations of government shipyards are also shown. In the main the figures are self-explanatory. The decrease in value of work done in 1909 compared with 1904 is due (1) to the dismantling of a large shipyard in Connecticut after the completion of the "Minnesota" and "Dakota"; (2) to a decrease in construction in Pennsylvania, and (3) to a reduction of output in one large establishment in California. The work in the establishments referred to in the last named states was largely for the government in 1904. The average government vessel launched in 1909 was very much smaller than in 1904. No battleship was launched from a government shipyard in 1909; the "Florida," under construction, was not launched until 1910. The battleship "Connecticut," of 16,000 tons displacement, and two steel training barks of a combined gross tonnage of 3600 were launched in 1904. This accounts for most of the great decrease in tonnage at government shipyards.

The statement of kind, number and tonnage is not that of vessels begun or advanced toward launching, but only of vessels launched, which may happen to be less numerous and important during the census year than those on the ways. Fewer ships were launched and the tonnage was less in 1909 than in 1904. The aggregate of all vessels of five gross tons or over launched at private and government yards, together with those at establishments engaged primarily in the manufacture of machinery, cars and lumber products showed a decrease of 28% for 1909 over 1904, but of only 13% in gross tonnage.

SHIPBUILDING IN THE UNITED STATES IN 1904 AND 1909

	1909	Per cent. of increase, 1904 to 1909[1]
General Summary: Private Shipyards		
Number establishments	1,353	23
Capital	$126,118,000	4
Cost of materials used	31,214,000	—17
Salaries	4,035,000	21
Wages	25,268,000	—14
Miscellaneous expenses	7,004,000	33
Value of work done	73,360,000	—11
Value added by manufacture	42,146,000	—7
Number officials and clerks	2,980	20
Average number wage earners	40,506	—20
Primary horsepower	88,063	13
General Summary: Government Shipyards		
Cost of materials used	$9,526,000	42
Salaries	2,647,000	279
Wages	12,670,000	30
Miscellaneous expenses	1,029,000	819
Value of work done	25,872,000	50
Value added by manufacture (work done less cost of materials)	16,346,000	55
Number officials and clerks	1,888	233
Average number wage earners	14,540	19
Vessels Launched: Private Yards		
Five gross tons and over[2]	1,584	—25
Gross tons	467,219	—7
Net tons	381,198	—10
Steel vessels:		
Number	158	2
Gross tons	254,986	65
Net tons	193,144	81
Wooden vessels:		
Number	1,426	—27
Gross tons	212,233	—39
Net tons	188,054	—41
Less than five gross tons	8,577	145
Steam, number	8	...
Motors, number	8,569	145
Vessels Launched: Government Yards		
Five gross tons and over	31	0
Gross tons	2,059	—92
Steel vessels:		
Number	3	—82
Gross tons	350	—99
Wooden vessels:		
Number	28	100
Gross tons	1,709	—50

[1] A minus sign (—) denotes decrease.
[2] In addition in 1909, eight steel and 14 wooden vessels of five tons and over, the steel having a total of 5429 and the wooden of 7106 gross tons, and 412 boats under five tons; and in 1904, three steel and 131 wooden vessels of five tons and over, the steel having a total of 498 and the wooden of 21,919 gross tons, and 365 boats under five tons, were made by establishments engaged primarily in the manufacture of other products.

Some Form of Sewage Treatment was in use by 27 of the 50 inland cities and towns on the smaller streams of Massachusetts on Nov. 30, 1910, the date of the last published report of the State Board of Health. On the same date five additional towns had treatment works under construction, leaving only 18 of the 50 cities without sewage-treatment works in use or being built. Although not directly stated in the report, it appears that few or none of the cities and towns on the Connecticut and Merrimac rivers have built sewage purification works.

Standpipe Failure at Sheboygan, Wis.

By Jerry Donahue*

A succession of very cold days lined the interior of the Sheboygan standpipe with ice and sealed its water contents with an ice cap. Internal pressure burst the standpipe at the base, along the line of an earlier partial fracture. Some of the lower rings were blown out to one side and the whole of the remaining structure fell in the opposite direction. The standpipe was 20 ft. in diameter, 140 ft. high and was erected twenty-five years ago.

*Of Donahue & Sinz, Civil Engineers, Sheboygan, Wis.

A standpipe failure which will be of interest to civil and hydraulic engineers all over the country, occurred at Sheboygan, Wis., on the evening of Jan. 15. An investigation revealed the following facts, which are herein presented in order that they may suggest to engineers interested in either the maintenance or the design of similar structures certain weak points which ought to be protected or eliminated.

The accident occurred at 5:55 p.m., at

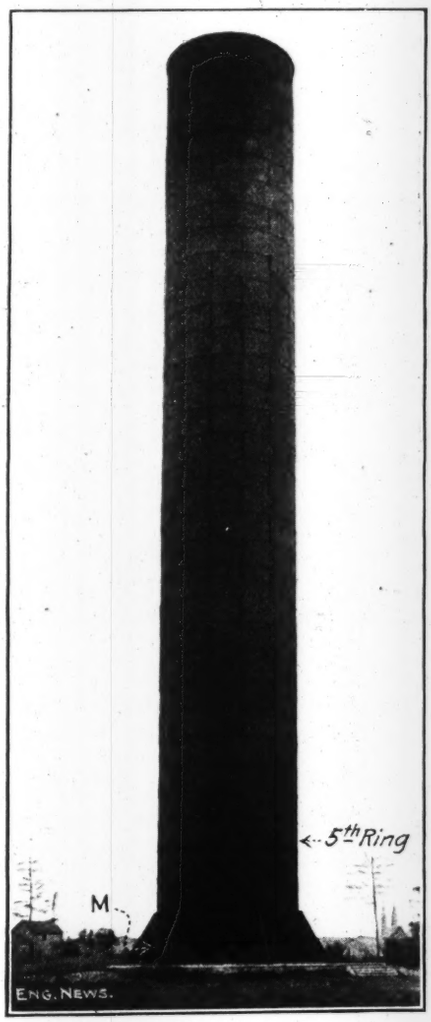


FIG. 1. STANDPIPE AT SHEBOYGAN, WIS., BEFORE FAILURE

a time following two weeks of severe cold weather. A tabulation of the maximum and minimum temperatures and the temperature at 3 p.m. on each day from the beginning of the cold weather to the time of the accident is given in the accompanying table:

The underlying cause of the collapse was undoubtedly the weakened condition of the plates and rivets in the bottom rings, brought on by nearly twenty-five years of exposure to the action of the water and ice. The direct cause, however, is of more interest to the engineer of the present as it may emphasize the importance of meeting such phenomena in the design of structures subjected to similar stresses. The failure was caused by expansion of ice which was permitted to accumulate to such an extent as to explode the lower sections. The cause of the formation of this ice will be discussed later, and proper conclusions may then be drawn by the reader as to how to cope with such conditions.

The water-works of Sheboygan were built in 1887 by the City Water Co., which subsequently went into the control of the American Water-Works & Guarantee Co., of Pittsburg, Penn. Since March, 1909, the works have been owned and operated by the city, under the direction of a commission which consists of the mayor and two citizens appointed by him.

In the proceedings leading to the purchase of the plant the entire system was appraised at $532,000, the physical value being placed at $396,000, and an additional going value of $136,000 being allowed. After some years of negotiations a price approximating $436,000 was agreed upon. The standpipe was included in this appraisal at $6585.

The water supply is drawn from Lake Michigan through an intake crib located 5000 ft. from the shore. The pumping station is equipped with three duplex double-acting pumps: an 8,000,000-gal. Nordberg, a 4,000,000-gal. Holly and a 3,000,000-gal. Gordon.

Sheboygan has an unusually large water consumption per capita, due to the fact that there are but few metered consumers. The daily consumption during normal conditions before the cold weather was 2,500,000 gal.; this was increased to 3,700,000 gal. when the cold weather came on. This increase was caused by the consumers leaving their faucets open during the night to prevent their pipes from freezing. At the time of the accident the Nordberg was running at the rate of 4,000,000 gal. in 24 hours.

The standpipe was erected in 1887 by a Buffalo firm. The original cost was approximately $13,000. Its location on a promontory in the northeastern section of the city has made it a conspicuous land mark for passing ships, its location being indicated as a bearing point on the charts used by navigators. Its base is 51.5 ft. above the level of Lake Michigan.

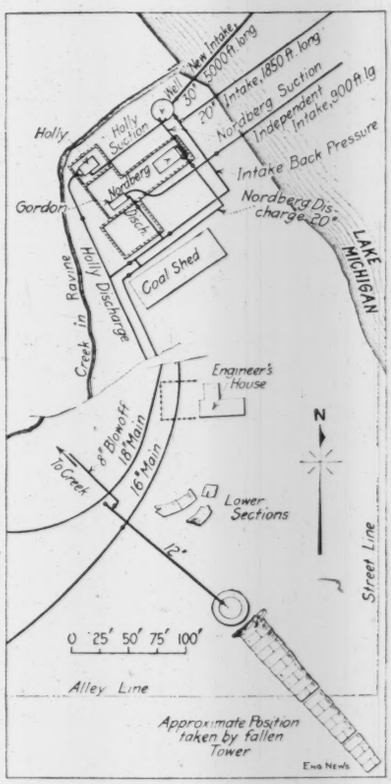


FIG. 2. PLAN OF WRECKED STANDPIPE AT SHEBOYGAN, WIS., IN RELATION TO PUMPING STATION AND ENGINEER'S HOUSE

RECORD OF TEMPERATURE AT SHEBOYGAN, WIS., JAN. 1 TO 15, 1912, IN DEGREES FAHRENHEIT

Date	Max.	Min.	3:00 p.m.
Jan. 1	+ 23	— 1	+ 4
" 2	+ 7	— 6	0
" 3	+ 8	— 8	+ 4
" 4	+ 5	— 7	— 6
" 5	—13	—17	—14
" 6	— 8	—22	—12
" 7	—10	—22	—14
" 8	+ 5	—15	— 1
" 9	+ 1	— 9	— 5
" 10	— 5	—19	—10
" 11	— 6	—16	— 6
" 12	— 4	—20	— 6
" 13	+ 11	—18	+ 9
" 14	+ 15	+ 9	+ 14
" 15	+ 16	— 6	+ 6

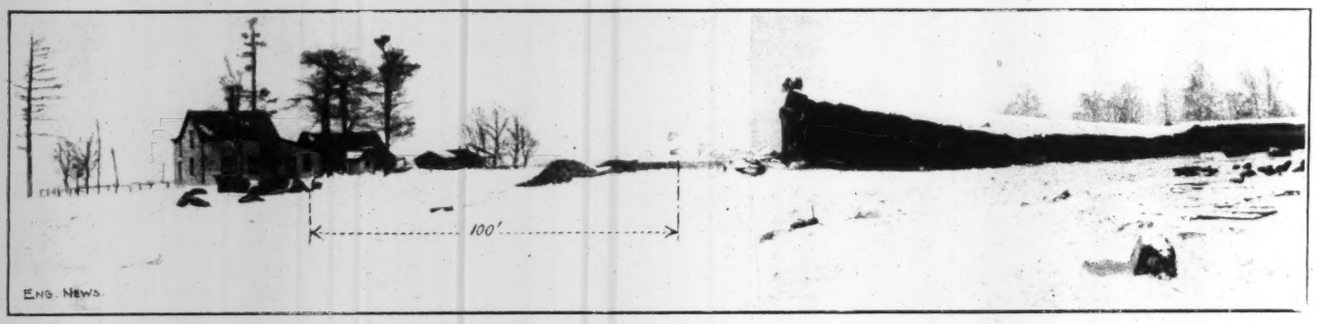


FIG. 3. GENERAL VIEW OF WRECKED STANDPIPE, SHEBOYGAN, WIS.

The standpipe (Fig. 1) was constructed of tank steel,* riveted into 35 circumferential rings. The plates were 4 ft. wide by 8 ft. 9 in. long. Their thickness ranged from $\frac{3}{8}$ in. at the lower sections to $\frac{1}{4}$ in. at the top. The vertical joints were double-riveted, with a 6-in. lap, and the six bottom horizontal joints were double-riveted, the single riveting beginning at the seventh joint from the bottom. Fig. 4 shows the last double-riveted joint and the first of the single-riveted joints. The rivets in the vertical joints were spaced $2\frac{1}{4}$ in. c. to c., the distance between the two rows being 3 in. The thickness of the plates at the bottom is less than would be recommended by hydraulic engineers at the present time. The formula,

$$t = \frac{2.6\,H.D.}{S.e}$$

gives a thickness of $\frac{1}{2}$ in. at the base, the H being 140 and the D being 20 ft.; S being taken at 12,000 lb. per sq.in. and e being taken at 75%.

The standpipe was inspected both inside and out in November, 1910, and although the steel on the inside was found to be badly pitted, due to the action of the water, no other serious defects were noticed at that time, and the inside was scraped and painted to check the inroad of the pitting. Fig. 4 shows the pitting on the inside of the fifth ring. Some of these pits are from $\frac{1}{16}$ to $\frac{3}{8}$ in. deep.

*The Manual of American Waterworks for 1897 says the standpipe was of "iron."—Ed.

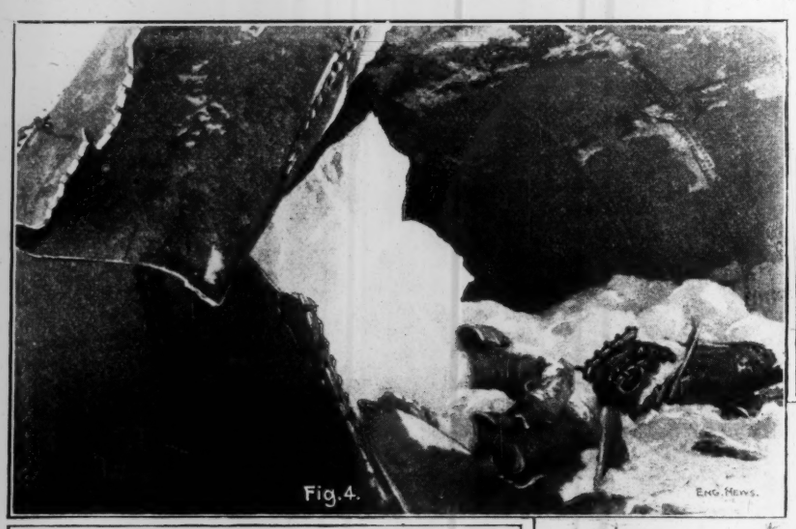


FIG. 4. LOOKING INTO LOWER END OF WRECKED STANDPIPE, SHEBOYGAN, WIS.

FIG. 7. FOUNDATIONS AND LOWER END OF STANDPIPE

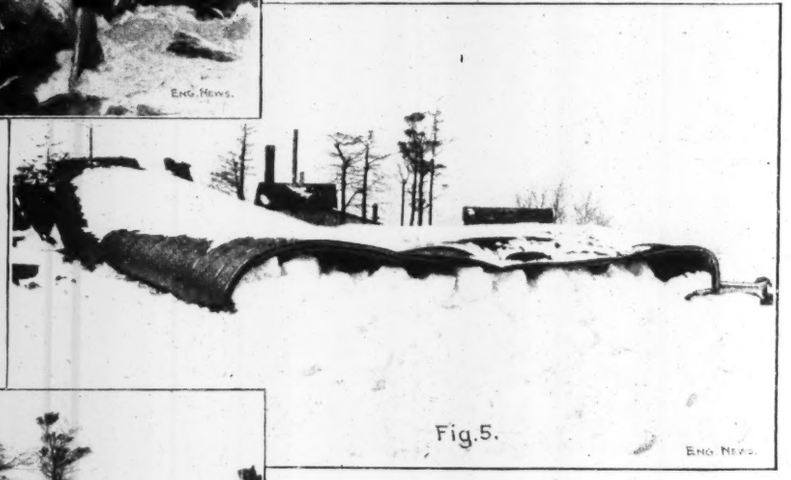


FIG. 5. BLOCKS OF ICE IN TOP END OF WRECKED STANDPIPE, SHEBOYGAN, WIS.

FIG. 6. LONGITUDINAL BREAKS AND ICE IN STANDPIPE

FIG. 8. FOUNDATIONS OF STANDPIPE ON RIGHT, AND LOWER FOUR RINGS THROWN OFF AT LEFT

Fig. 1 shows the standpipe as it appeared before the failure. It stood 140 ft. above the foundation, the diameter being 20 ft. The photograph was taken looking toward the southwest, and clearly shows the 35 rings and the braces at the bottom which anchored the tower to the foundation.

The foundation is of stone, circular, 30 ft. in diameter, and 16 ft. in depth. The six anchor bolts are 2½ in. in diameter and are embedded about 12 ft. The manhole used for entering the tower for inspection is indicated by *M*, Fig. 1.

The standpipe is connected to the mains leading from the pumping station by one 12-in. pipe, which is tied on to both a 16-in. and an 18-in. main. Fig. 2 shows the connections to the system. The 12-in. main enters the tower through the center of its base. Here a piece of 12-in. pipe, 6 ft. long, is flanged on so that the water enters about 6 ft. above the base-plate. The details of these connections are shown in Fig. 2. The valve for cutting off the standpipe from the distributing system is under the tower, and is accessible through a trap leading in from the side of the foundation. This valve is closed when a pressure of greater than 60 lb. is required for fire fighting.

As stated, the underlying cause of the collapse was the weakened condition of the plates and rivets in the bottom rings. Observation of the wreck shows that a force sufficient to have ruptured stronger plates must have been acting to produce the conditions shown by Fig. 3. The direct cause of the failure was the expansive force of the ice which had formed in the tower. This formation was accelerated by poor circulation between the mains and the standpipe.

The circulation growing poorer each year as the demand for water increased, made it necessary for the pumps to run continuously, thereby holding the pressure sufficiently high to supply this demand, the standpipe merely acting as a balance on the system. An examination of the pressure records corroborates this fact. The records before the failure show a comparatively smooth curve, and since the failure the records show a fluctuation due to the varying load.

The standpipe was cut off on Jan. 9, between 7:30 a.m. and 4 p.m., while the pumps were supplying a pressure of 110 lb. for fighting a fire. An examination of the temperature records for the day show that the temperature was considerably below the freezing point all day. These conditions, together with the fact that the temperature of the water entering the tower was only a few degrees above the freezing point (35° F. at the time of the failure) are responsible for the formation of an ice cap at the top, and a thick layer of ice at the bottom, the intervening space being partially filled with a circumferential lining measuring 24 in. in thickness. Fig. 4 shows a block from this lining. This ice was molded in concentric rings or laminations, showing the effect of successive cold periods, some rings being ½ in. in thickness, others 2 in. or more.

Fig. 5 shows the ice thrown out from the top of the tower. Here, too, were found blocks of ice over 4 ft. thick, the appearance of which indicated that the laminations were horizontal, and that the block was a part of the cap which sealed the top of the water column.

The amount of ice which fell with the tower was approximately 950 tons. Figs. 5 and 6 show the upper two-thirds of the wrecked tower almost filled with ice. The ice in the lower third was thrown out by the rush of water when the collapse came.

A study of the fractures indicates that failure first occurred along a vertical seam in the bottom ring. The two angles forming the heel which fastened this ring to base plate failed by a longitudinal fracture along the vertex, and the shearing off some of the rivets in the horizontal legs. An examination of these angles revealed an old fracture which showed up for several feet adjacent to the vertical seam which first gave way. This fracture was on the inside of the tower and was undoubtedly caused by the expansion of ice in former winters. After the seam opened up in the lower ring, the line of rupture ran up to the top of the fourth ring. It followed an irregular course, shattering the plates and shearing off rivets. At the horizontal joint between the fourth and fifth rings it followed around the whole circumference. The plates in the sections which peeled off showed effects of an explosion; the report of this explosion shook the engineer's house, shown in Fig. 3, similar to an earthquake shock. This explosion was followed by the crashing of the standpipe, about twenty seconds later.

Fig. 3 shows the bottom rings, which were thrown northwesterly and now lie 100 ft. from the foundation. This part includes the manhole, shown in Fig. 1, and four of the six braces which tore loose from the anchor bolts. Another of the braces was thrown 150 ft. northeasterly. The sixth still clings to its anchor.

One anchor bolt sheared off between the plate and the angle; the others are badly bent and distorted.

After these lower rings peeled away the rest of the standpipe dropped directly to the foundation. Figs 4 and 7 show the distorted shape of the fifth ring, which buckled under the impact before the tower toppled over. The standpipe fell in a southwesterly direction, directly opposite that in which the lower sections were thrown.

The impact of the fall broke the standpipe into three sections (see Fig. 6), the 14th and 20th horizontal joints from the top opening up. The recording pressure gage (located in the mayor's office) for Jan. 15 shows a pressure of 50 lb. up to 5:55 p.m., when it dropped to 5 lb. The pressure at the pumps dropped from 80 to 25 lb.

The standpipe will probably not be replaced. The commission has the matter under consideration and it is expected that suitable additional pumping machinery will be installed instead.

The Pollution of Streams Used for public water supplies in the State of Wisconsin, in such a manner as to be a public nuisance, detrimental to health, may be stopped by the State Board of Health under an act passed by the Wisconsin legislature in 1911. (Chapter 412.) The act also enables the State Board of Health to prohibit the use of impure water for drinking purposes. Complaints of sewage or other water pollution may be made to the State Board of Health by the governing body or the board of health of any municipality or township of the state, whereupon it becomes the business of the board to make an investigation. If the board finds that the complaint was warranted and that contamination exists which is detrimental to the public health, it must so notify the municipality or individual causing the pollution, and give a hearing thereon within 15 days. If the board concludes after such hearing that improvements or changes in sewage disposal are necessary for the preservation of health, it must report its finding to the governor and upon his approval must then notify the municipality or corporation or person involved to install necessary works for purifying or otherwise disposing of the sewage or wastes in such a way as may be necessary to preserve the public health. The right of appeal from such an opinion or order is provided for by this act. In case of such an appeal two reputable and experienced sanitary engineers are to be selected, one by the offending party and the other by the State Board of Health. In case of disagreement on the part of these engineers they are permitted to choose a third engineer. The vote of a majority of these engineers shall be considered the decision of the referees. The opinion of the referees, when reported to the board in writing, is to be enforced by the board. The fees and expenses of the referee engineers are to be paid by the municipality or by the corporation or by the person requesting the appointment of the referees. The act also provides that no town, city, village, public institution, individual or water or ice company shall use water or ice which is so contaminated, unwholesome and impure, that the use thereof will endanger the public health. After investigation, the State Board of Health may prohibit the use of such contaminated or impure water. The orders of the board in such cases are enforceable by the State Circuit Court. It may be added that the control of private water companies and of municipally-owned water-works vested in the Railroad Commission of Wisconsin gives that commission jurisdiction over the "adequacy" of all public water supplies. We are informed by Prof. Wm. D. Pence, chief engineer of the commission, that it is now customary for the commission to refer sanitary questions to the State Board of Health for investigation before taking action on the "adequacy" of water supplies.

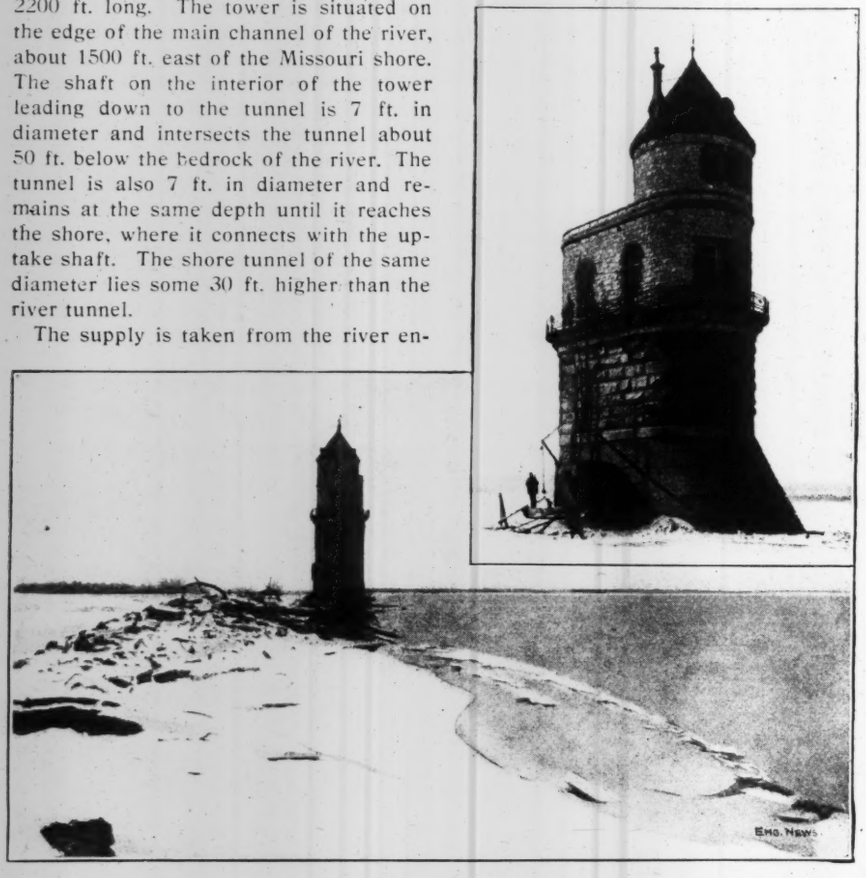
Ice Trouble at the Saint Louis Water Works

By Edward E. Wall*

The water supply for the City of St. Louis is taken from the Mississippi River through an intake tower and tunnel about 2200 ft. long. The tower is situated on the edge of the main channel of the river, about 1500 ft. east of the Missouri shore. The shaft on the interior of the tower leading down to the tunnel is 7 ft. in diameter and intersects the tunnel about 50 ft. below the bedrock of the river. The tunnel is also 7 ft. in diameter and remains at the same depth until it reaches the shore, where it connects with the uptake shaft. The shore tunnel of the same diameter lies some 30 ft. higher than the river tunnel.

The supply is taken from the river entirely on the east side of the tower through four gates, three of which have a sill elevation of 72. The fourth gate is 4 ft. lower and its sill is at the bedrock of the river. The three gates first mentioned are covered by gratings to prevent the entrance of floating logs, débris or ice. Two of these gates have openings 3x4 ft.; the third, 4x6 ft.; the fourth gate, at the bottom of the river, has an opening 5x5 ft., and is unscreened. It was the original intention to use this gate only as a last resort, when the water was too low to flow through the other gates. It was fully appreciated that ice and drift would freely enter this gate whenever it was used. Of recent years, the river has several times been at so low a stage that this gate had to be frequently used.

On Jan. 1, 1912, the stage of the river was about 82, but it rapidly fell until it became as low as 76.5. This lower 5-ft. gate had to be opened on Jan. 1 because of the obstruction to the passage of water through the upper gates, caused by ice lodging against the screens of the other gates. Needle and slush ice passed through these screens with the water to such an extent that it became a menace to the operation of the pumps early in the evening of Dec. 31, 1911.



Figs. 1 and 2. The Ice Drift at the Chain of Rocks Intake, St. Louis Water Works

The devices for removing ice from the wet-well (to which the suction pipes of the pumps are connected) consist of two inclined elevators carrying buckets holding about 3 cu.ft. and travel at a rate of about 35 ft. per min. Each of these machines is capable of discharging approximately 30 cu.yd. of ice per hour. Under ordinary conditions their capacity is amply able to take care of the ice that comes into the well.

On Sunday evening, Dec. 31, 1911, at 5 p.m., the ice began to rapidly accumulate in the wet-well. Both ice elevators were put in operation, but the ice came in faster than it could be removed and the machine became more and more heavily loaded. At 10 p.m. the worm-wheel of the north machine broke, and at 11 p.m. the chains carrying the buckets on the south elevator broke, thus putting both machines out of service. On Monday morning, Jan. 1, 1912, the outlook was very gloomy, the well full of ice, only enough water to supply one pump coming through the tunnel. Monday being a holiday, the employees of the department were mostly off duty and it was difficult to collect men enough to accomplish anything. A derrick and hoisting engine belonging to the department were erected at the well, and inquiries started in every direction for machines which could be used for lifting the ice from the well. From the wreck of the south ice elevator, the north elevator was repaired and put in service. On Tuesday a derrick was obtained from the Terminal Railroad Association, and a clam-shell bucket from the Union Sand & Material Co. Late Tuesday night it was found that the derrick would not operate the bucket. Another derrick was obtained from the Terminal, but on bringing it over the Water-Works Ry. about 5 a.m.,

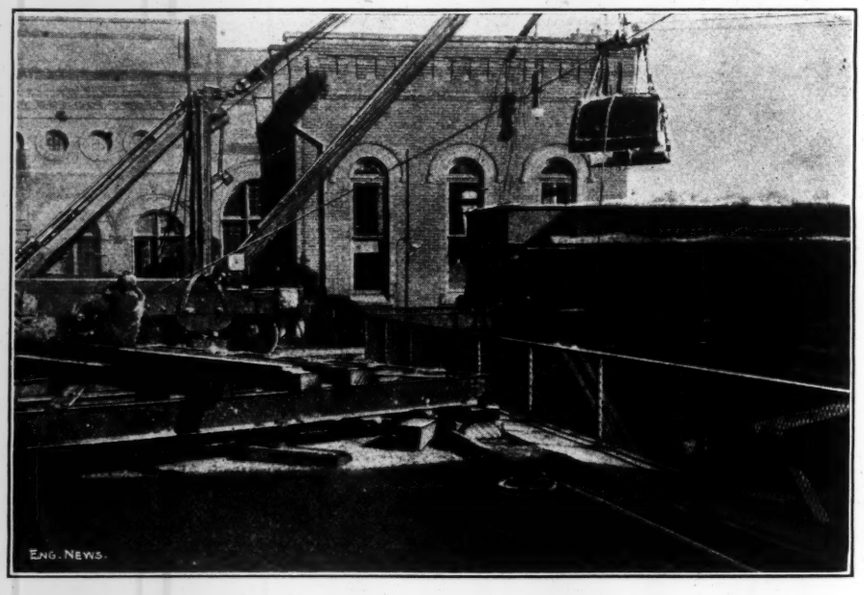


Fig. 3. Using Clam-shell Bucket to Take Ice from the Wet Well, St. Louis Water Works Pumping Station

*Water Commissioner, St. Louis, Mo.

Wednesday, it was found that it would not pass under the bridge at the Burlington R.R. by 15 in. Trackmen from both the Terminal and the Burlington were obtained, and in spite of the frost, 75 men lowered the track and the derrick was brought to the Chtain of Rocks at 3 p.m., Wednesday. Another engine, derrick and clam-shell bucket, obtained from the City Construction Co., was taken down Tuesday night and Wednesday transported to the Chain of Rocks, erected and put in service Thursday night. On Thursday evening the wormwheel of the north elevator gave way, putting this machine again out of service. New wheels had been ordered by wire to be sent by express from Philadelphia. These wheels had to be cast and the gear teeth cut special, so that the first was received Monday morning, Jan. 8. The derricks operating the clam-shell buckets were operated day and night until the well was finally cleared of ice by Wednesday, Jan. 11. During the whole ten days the rate of pumping varied from 40 million per day to 90 million, the average being not more than 60 million.

The daily consumption of water for the first eight days of January averaged 100 million gal., so that by Tuesday morning, Jan. 9, the total reserve of 400 million gal. which was on hand Jan. 1 had been practically exhausted and the basins were almost empty. Under these conditions it was necessary to stop the addition of lime and sulphate of iron, since the flow through the basins was too rapid for sedimentation to take place. For two days water was pumped directly from the river into the mains, but the purification process was resumed on Thursday, Jan. 11, at 11 a.m.

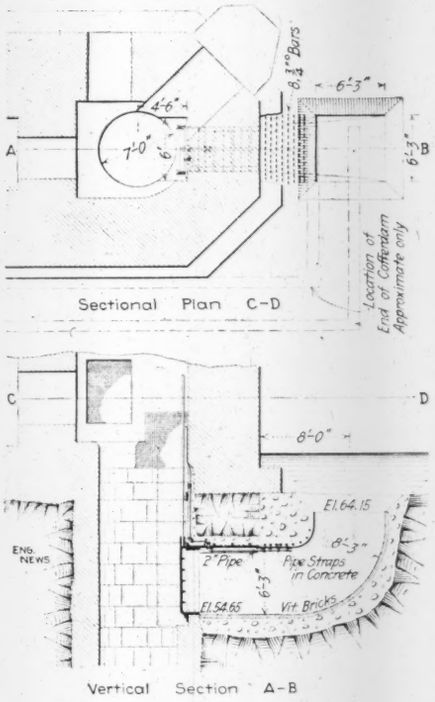


FIG. 4. BASE OF CHAIN OF ROCKS INTAKE, ST. LOUIS WATER WORKS, SHOWING INLETS AND PROPOSED NEW INLET

On Tuesday night, Jan. 9, a gorge formed below the Municipal Bridge and later above the Eads Bridge, producing a rise in the stage of water at the intake tower, so that by Wednesday noon it was possible to operate five pumps, delivering water to the basins at the rate of 150 million gal. per day, a rate of pumping which was never before reached in the history of the water-works.

Although there has been serious trouble several times during the previous winters, it has never assumed such dangerous proportions as on this occasion. Taking into account the low stage of the river and the exceedingly cold weather, producing an ever-increasing quantity of needle and slush ice, the situation seems to have been about as severe as is possible to occur in this climate.

Previous troubles had shown the Water Department the necessity for another and a lower gate in this tower, and a contract was let last July for cutting an opening in the south end of the tower several feet below bedrock with a short tunnel and shaft opening directly on the bottom of the river. A section of this gate is shown in Fig. —. Unfortunately, unexpected and exceptional difficulties were encountered in sinking the caisson for this work and floating ice forced a suspension early in December.

With this gate completed and some additional devices for keeping the ice away from the tower gates, it will be possible, no doubt, to obtain water for this city for a number of years. There is no doubt, however, that a city of this size should not be dependent on a single intake and tunnel, and surveys will be started at once and plans made for the construction of an additional intake and tunnel.

Letters to the Editor

The Doom of the Independent Producer

Sir—Once more I had hoped that my latest communication on government competition (ENGINEERING NEWS, Jan. 11, p. 71) might be my last; but once more your reply forces me to tax your patience.

You admit the possibility of a future for "The Civil Engineer's Pocket-Book," provided the government, in competition, ties its hands behind its back by charging its customers "the full cost of compilation, editing, printing, etc.," but you say that "when the government gives pocket-books away, Mr. Trautwine will have no fair chance."

Again I must dissent, repeating that "fairness does not require the handicapping of the stronger competitor," even if we happen to be the weaker one.

Not only governmental bureas, but large manufacturing concerns, have published pocket-books, distributing them at nominal rates, or even gratuitously; but, so far from calling such competition unfair, or clamoring for protection against it, we have cheerfully consented to their use of our material, recognizing that the public is entitled to the best and cheapest service it can get, whatever may happen to the individual worker.

Within the next half-century the private engineer and his privately published pocket-book will have gone the way of the private pump and well, and with similarly happy results all around. The public will be better served, while the engineers and the pocket-book makers, instead of "struggling to make a living by independent practice," as at present, will be in snug places at the public crib.

JOHN C. TRAUTWINE, JR.

257 S. Fourth St.,
Philadelphia.
Jan. 12, 1912.

[We *did* intend to let our valued correspondent have the last word this time, but his closing words are too much. "Snug places at the public crib" tells the story why the municipal or state or national government or the huge trust is handicapped in any fair race with a live competitor who may be "struggling," but who has something big to struggle for. How a Philadelphian can believe in governmental efficiency passes our comprehension.—ED.]

Sir—The editorial reply to Mr. John C. Trautwine, Jr., in ENGINEERING NEWS of Jan. 11, impresses me as being clever rather than convincing.

That the Trautwine pocketbook has a reputation established which makes it to a degree exceptional, does not militate against Mr. Trautwine's general contention. The writer of this has a copy of "Trautwine" and it has on the flyleaf the

name of the publishing house of John Wiley & Sons, which is a pretty big concern.

However, if Mr. Trautwine undertook to put out his book on his own hook, and he was met by a big trust which would sell a similar book at cost of production, or less, till such time as he was driven from the field, the trust then putting up the price so as to recoup itself for what it had lost in the fight, it would be similar to the situation which faces the small business man who undertakes to "buck the trust."

The map company which has a practical monopoly of the production of insurance maps in the United States, did this very thing in the city of Cincinnati a few years ago. The same company charges enormous prices for its maps, but, for the reason that it is so powerful, no one dares to enter the field against it. It would make a campaign in the special locality in which the rival concern was operating, putting the price down to any figure that would be successful in driving out the competing concern. After the concern was driven out, there would be an advance in prices.

If any fact has been established in the economic history of America, it is the superior efficiency of the big combination in business; that we are outgrowing the age of free competition and entering on that of industrial combination.

The trust is the most efficient engine of social production that has yet been evolved. Therefore, according to the law of the survival of the fittest, the trust exists. It triumphs because it is best equipped to cope with all obstacles that may impede its progress.

Maybe Mr. Trautwine will agree that beyond the era of trustification another colossal social force already looms.

THOMAS FLYNN.

New York, Jan. 14, 1912.

[Yet Mr. Carnegie, in his testimony before the Stanley Committee, at Washington, recently, declared that a private firm made up of active and alert partners could "run all around any corporation." —ED.]

Controlling the Lower Colorado River; Lessons from Mississippi Levees

SIR—The two communications in ENGINEERING NEWS of Dec. 7 on the subject of the lower Colorado River, by H. T. Cory and J. A. Ockerson, respectively, contain much matter of interest to engineers in general, and especially to one who is familiar with the levee problem of the lower Mississippi River.

The writer does not propose to enter into the controversy between Mr. Cory and Mr. Ockerson. He desires, however, to offer some reflections on the problem of protecting the Colorado River levees from current erosion, derived from his own experience in combating such destructive current energy in situations that bear some analogy to that under discussion.

It seems evident that the destruction of portions of the levee built by Mr. Ockerson was directly due to the diversion of a current by the thick growth of brushwood on the borrow pit traverses, against the raw slope of the levee, composed of silty and yielding material but recently placed.

Mr. Ockerson's proposed remedy for this trouble (extending brush "tapoons" down the levee slope and connecting them with the brushwood on the traverse) appears to the writer of questionable value under the conditions described. On the other hand, his own experience indicates that any obstruction placed in the line of flow of a strong current, with the resultant provocation to local concentration of energy, should be so located as to remove the point of such concentration to a safe distance from the structure to be defended.

The writer has for many years past occupied the place of chief engineer of the Upper Yazoo Levee District in Mississippi, and during that time has done much battling with the destructive forces of rapid currents.

Along the river front of this levee district are six localities where the levee alinement makes short cuts across the necks of peninsulas formed by great bends in the Mississippi River. In these localties the flood slopes assume abnormal steepness and generate currents which have threatened the levee with destruction. These "short cuts" are from two to six miles long, and on one of them the flood slope in 1907 dropped 4.5 ft. in the first two miles, about half of which drop was concentrated in the vicinity of the salient in the levee line at the upper end of the stretch.

In the great flood of 1897 a breach was made in this levee line under conditions quite similar to those experienced by Mr. Ockerson. At that time there existed a "main front line" of levee extending 94 miles from the upper end of the district and terminating at the south end of the river bank, or "in the air," in military phrase. Another line of levee extended from the southward overlapping the lower end of the front line, with an open basin lying between. The last four miles of the front line was a "short cut" with a steep slope. Here had been a recent enlargement of the levee, consisting of very silty and nonresistant material; and a heavy growth of timber on the right of way had been cut down and left on the ground. The flood water gathered up this timber into rafts, which found anchorage along the line of borrow pits a short distance out from the levee slope, by which the current was diverted against the raw levee enlargement. A strenuous fight was made to hold the levee by the use of short brush dikes down the slope and earth sack revetment, handicapped by stormy weather and by the presence of back water behind the levee well up on the rear slope. After three days and nights of hard fighting with a rapidly rising river, the current made a breach through the levee, but did no material harm in this case, as the escaping water merely pursued a shorter route into the river a few miles below.

As a general result of the writer's experience in this field, based upon many a hard-fought battle with river floods, he has found it expedient as a basic principle, wherever violent currents are encountered, to give the water all possible freedom of flow, by removing every kind of obstruction from its path, as borrow pit traverses, stumps, bumps, trees and logs; and clearing a wider waterway through timber growth, the logs being cut up into short lengths to float away without collecting into rafts.

Traverses left across river-side borrow pits act as "tumbling dams" at certain flood stages, and the effects once started are accentuated by higher stages, resulting in the scouring of large and dangerous holes, in many cases in the writer's experience. Likewise, large stumps left in the pits, trees and anchored drift logs, obstructing the freedom of the flow, provoke violent scouring action of the current. The major feature, however, of this system of defense is to remove the line of flow to a safe distance from the levee line. This is accomplished by the construction of "spur levees" from one hundred to two hundred feet long, projecting from the main levee toward the river, slightly inclined down stream to avoid setting up eddy action above the spur.

During the flood of 1903 one of these spurs, on a salient where the current was extremely violent, was the scene of a strenuous fight and the cause of much anxiety for the safety of the levee. The chief cause of the trouble was the excessive length of the spur, which projected about 300 ft. from the levee line at a salient with 60 deg. deflection, and left insufficient waterway between the head of the spur and a wall of forest opposite.

Through this restricted opening a tremendous volume of water, 14 ft. deep, rushed around the head of the spur by a short turn and a very steep slope, scouring a hole about 150 ft. long, 100 ft. wide and 20 to 25 ft. deep. Vigorous work was required for several days and nights, with the use of sack wreaths and brush fascines, to prevent the spur from washing away, back to the main levee.

There is, of course, lack of analogy between a current flowing around a pronounced salient with concentrated fall, and that running generally parallel to a comparatively straight line of levee, the conditions being much easier to control in the latter case.

The problem of protecting the heads of the spur levees from attacks of the current was, after the experience of 1903, solved in a quite effective and satisfactory manner. This was by the use of a wooden bulkhead around the head of the spur, built in the following manner: 2x12-in. plank, 16 ft. long, were driven in a close row around the head of the spur, and extending well back on the up-stream side, and a short wing projecting beyond the down-stream corner to prevent the current from whipping back on the lower side. The planks were driven 10 ft. into the ground and projected 6 ft. above it. To the projecting ends other 2x12 plank were spiked on, extending from the ground to bulkhead grade, above flood height, 12, 14 or 16 ft. The joints were battened with 2x6-in. plank; waling timbers were placed at the top and near midheight of the vertical wall, and from the latter ⅝-in. wire cables were run to anchorage in the spur. From the end of the upper wing a cross wall was carried into the side slope of the spur up to bulkhead grade. From the bottom of the vertical wall a horizontal "apron" 10 ft. wide was built of two thicknesses of 2x12-in. plank, the outer edge resting on the top of a double row of 2x12-in. sheet piling, driven 10 to 12 ft. into the ground.

These wooden bulkheads, built of creosoted lumber, were found very vulnerable to fire attacks, two having been burned last spring, from burning Bermuda grass. These have been replaced by concrete slab work, the slab being 4 in. thick, laid on a slope of 2½ to 1, from the crown of the spur to the base, and extending horizontally from the foot of the slope to form the "apron," the outer edge of which rests on the head of the sheet piling, and extends down 1.5 ft. below the pile heads on the outside. The concrete mixture is cement, sand and gravel, in the proportions 1:3:6. Two horizontal rows of "weep holes" were placed, 1.5 and 6.5 ft. above the foot of the slope, by inserting short sections of 1-in. pipe, 1.5 ft. apart, while the concrete was still plastic, and withdrawing them in a short time to be inserted again further along.

There are 13 of these spur levees along this line of levees, all exposed to the attacks of violent currents in deep water; but no trouble has occurred with any of them since the above described defenses have been in use.

With the lights before him, the writer would suggest, tentatively, in the case of the Colorado River levees: (1) That the borrow pits be on the river side; (2) that the pits be made continuous, clean and without traverses, and the section be made as symmetrical as practicable; (3) that the berm be not less than 80 ft. wide; and (4) that a series of spur levees be built from the main line to the margin of the pit, the heads of the spurs defended as stated above, and placed at such intervals as the engineer's judgment may indicate.

In the various publications that have appeared on the subject of the Colorado levees, allusion has been made to borrow pits on the land side, and the comparative merits or demerits of such location discussed. The writer is disposed to regard borrow pits on the land side of any levee as generally undesirable and in many cases a menace to the stability of the levee. With the character of soil as described along the lower Colorado, this observation would seem to apply with especial emphasis, unless an impervious barrier in the form of a "muck ditch" can be interposed beneath the levee with certainty of its proper performance.

The writer has dealt, in numerous cases, with treacherous levee foundations under aggravated circumstances and under heavy hydrostatic pressure. The most successful method of combating this danger is by ponding water over the treacherous expanse behind the levee, as it can be covered with water with greater facility and less cost than with other material. This is done by temporary expedients during the exigency of a "high-water fight," to be made permanent when more time is available. The method employed is to build "sublevees" behind the main levee, high enough to pond the water from 4 to 10 ft. deep over the region of weakness, according to the conditions to be met. It is usual to build two wings back from the main levee, across borrow pits if there be any, and a "curtain" to connect the wings behind. A spillway is placed over the sublevee to prevent overtopping, and a drain pipe, with valve, under the sublevee to drain the inclosed basin when no longer necessary to retain the water.

This device serves the double purpose of diminishing the hydrostatic head on opposite sides of the levee, and of providing a dead-water cushion over the orifices of "spouts" or fountains which bring up material that is displaced beneath the surface, preventing such material from flowing away, and stopping the progress of such underground displacement.

In large basins having several acres area it has been found expedient to hasten the filling of the basins on a rising river by the use of 8-in. siphons over the levee, the intakes of which are placed low enough down the levee slope to come into action before great pressure is brought to bear by higher stages of the river.

In the writer's practice this method of treatment has proved entirely effective in controlling the danger of weak levee foundations.

There are some 25 permanent "sublevee basins" along this levee system.

T. G. DABNEY.

Clarksdale, Miss., Jan. 15, 1912.

Land-Side or Water-Side Borrow Pits in Levee Building: Comments Prompted by the Colorado River Problem

Sir—The letter written by Brig. Gen. Wm. L. Marshall, published in ENGINEERING NEWS of Jan. 11, which discusses the relative merits of river-side and land-side borrow pits for levee construction, has been read with much interest. The writer, as United States Assistant Engineer, has worked under several levee specifications that were no doubt evolved from the specifications first written by the Board of Engineer Officers of which General Marshall was a member. After giving two reasons for the specifying, by that Board, of river-side borrow pits, General Marshall's letter contains the following paragraph:

> If there be any other reasons than the economical ones stated above, for the rule that material for levees should be taken from the river side, I have never heard of them, and none are given by either Mr. Corey or Mr. Ockerson. It would be of great interest if they were stated and clearly explained.

The writer believes that there is a reason of much greater moment than either of those which influenced the adoption of the river-side borrow pit in the specifications written in 1882. In the Upper Yazoo (Mississippi) and Lower White River (Arkansas) Levee districts, where no question is involved of the eroding action of flowing water along a land-side borrow pit, an excavation on the land side is nevertheless believed to be a source of weakness to the levee, *because of the breaking of the surface crust.* For a great extent of each of the districts named (and doubtless of all other districts along the Mississippi River below Cairo, unless exception can be made of those in southern Louisana where the "buckshot" formation predominates) it is impracticable and uneconomical to make a muck ditch deep enough to penetrate all of the porous substrata, and these are charged with seepage water. Usually the small quantity of this water which finds its way to the ground surface behind the levee, where such surface has remained unbroken (or better still is covered with bermuda sod), does no harm except to contiguous crops. The excavating of a borrow pit on the land side of the levee reduces the resistance to the passage of this seepage water, thereby, in many cases, greatly accelerating its flow. A marked characteristic of the ground in many portions, if not all, of the alluvial area of the Lower Mississippi Valley is that the surface stratum is usually more impervious than the material immediately underlying it.

The writer has many times seen "sloughs" start in the edge of a land-side borrow pit and work toward the levee, and the worst "sand boil" that he ever treated was in a land-side borrow pit some 50 or 60 ft. from the base of the levee. He has seen many more sand boils of such consequence as to attract notice, in land-side borrow pits than on unbroken ground.

In the Yazoo-Mississippi Delta Levee District, of which the writer was assistant chief engineer, the land-side borrow pit has, for years, been recognized as a weakness in the system, for the reasons given above. During the later years it has been avoided wherever practicable.

A. L. DABNEY, Chief Engineer,
Tallahatchie Drainage District.

Tunica, Miss., Jan. 20, 1912.

Sir—Wm. L. Marshall, Brig. Gen., U. S. A., retired, in ENGINEERING NEWS, Jan. 11, 1912, page 75, after giving two reasons for locating borrow pits on the land side of the levee says:

> If there be any other reasons than the economical ones stated above, for the rule that material for levees should be taken from the river side, I have never heard of them, and none are given by either Mr. Cory or Mr. Ockerson. It would be of great interest if they were stated and clearly explained.

His two reasons are good and applicable to most kinds of soil, but I think do not extend far enough to secure safety in regions of quicksands. To show the action of quicksand during the approach, as also the receding, of high waters I beg to quote H. S. Taber, Captain Corps of Engineers, U. S. A., on page 53 of *Transactions* of Arkansas Society of Engineers, 1887. In describing the condition of the Arkansas River at Pine Bluffs, he says:

> In 1883 and 1884 the river acted with such force upon the town front as to cave off 120 ft. of the bank at one point measured at right angles to the current. At that rate the courthouse and many other valuable buildings would have gone in another year. This heavy caving was aggravated by the presence of an underlying stratum of quicksand extending back miles under the country probably. When the river is very high the water is forced back into the country through the quicksands, and when it falls again this water returning to the river brings the quicksand with it and near the river bank the superincumbent mass of earth having its support taken away, caves into the river in large sections, revealing to the practiced eye the exact cause of the caving, inasmuch as caving due to the friction of the current against the bank is slower and more regular. Clearly, to be brief, any thing that will prevent this quicksand from being washed out, will stop the caving.

Sny Levee is 52 miles in length, situated along and near the east bank of the Mississippi River, through Adams, Pike and Calhoun Counties, Illinois. It was constructed in 1872 to 1874 and reclaims 110,000 acres. We have had water against portions of the levee continuously for 120 days, and it was 90 days before the maximum waters came, which, together with the rainfall, fully saturated all of the low lands. Many portions of the levee are underlaid by the character of material, quicksand, described by Captain Taber. I have many times seen verifications of the above actions of quicksands under the levee into the borrow pits and a few times from the land side to the river side when the water was higher on the land side.

During one high water a patrolman observed very muddy water coming down a seepage ditch 3 to 5 ft. deep and 100 ft. from the levee. Hastening to its source he found the quicksand being carried into the ditch rapidly and the superincumbent earth falling into the ditch. Before assistance and material could be gotten there and the caving stopped (about an hour) it had reached about half way to the levee. About two hours more would undoubtedly have taken the levee away at that point. In this case there were no borrow pits—nothing but that ditch to intercept the seepage water, but it removed the covering of the strata of quicksand, thereby giving it an opportunity to move.

In constructing the north one-fourth to one-half of the levee, borrow pits on the land side were prohibited. Financial conditions then became such that it was not a question of following the engineer's specifications for a good levee, but a question of getting a levee the full length of the 52 miles. To get a minimum height of embankment it was located along the banks of sloughs so that it became almost imperative to get material from the land side. This was through a region of very fine quicksand. About one-third of all the crevasses have been in this region, and generally this region of about 10 miles has cost more for high-water expense and maintenance than all the balance of the levee.

To remedy it we have covered almost the entire slope of the borrow pit next to the levee with a heavy banquette having generally 4 or 5 to 1 slope extending into the pits, also a 4 to 1 slope from the banquette to near the top of the levee.

By removing surface soils of 1 to 4 ft. from the strata of any of the sands you induce a much larger volume of seepage water.

Borrow pits on the land side increase the *total head.* I have known the outlets of seepage water to be dammed for the sole purpose of retaining the water to decrease the destructive force of the total head.

After 14 years' experience with this levee and considerable observation in other states I favor an almost iron-clad specification *to permit no borrow pits upon the land side of the levee.*

E. J. CHAMBERLAIN,
Engineer, Sny Levee.

Pittsfield, Ill., Dec. 20, 1912.

Sir—In regard to the discussion on borrow pits in your issue of Jan. 11, 1912:

The writer was for some time connected with levee and drainage work along Kings River, in the great interior valley of California. The flood flow of this stream, when the snow melts in the Sierras in May and June, runs from 10,000 to 30,000 cu.ft. per sec. On about 30 miles of the lower course of the river, the channel, while well defined, is inadequate for even the lesser of these amounts, while still further down, there was originally no defined channel, and what natural sloughs and short stretches of dredged channel now exist are wholly inadequate for the flood flow.

In this region the main advantages of borrowing on the river side are as follows: (1) The cross section of the channel is increased. (2) Valuable land is not sacrificed. (3) There are fewer stagnant, mosquito-breeding pools. (4) The levee can be strengthened with teams even during high water. This is particularly important in the smaller reclamation districts, where, after the levee is first constructed, little or no engineering advice or supervision is obtained. Nearly all maintenance work is left until the early spring, when reports of great depth of snow in the mountains usually result in a hasty meeting of the farmers of the district, followed by spasmodic strengthening of the levees all along the line. At this time the land-side pits are usually full of seepage water, making team work difficult if not impossible.

The danger of the water-side pits cutting out and bringing a dangerous current against the levee itself, besides undermining it, can be guarded against either by specifying a wider berme or by not making the pit continuous. The latter method minimizes advantages (1) and (3). The former method may make the levee cost a little more at first, but is worth it.

It might also be noted that in case the levee does break, the erosion of a land-side borrow pit causes much more serious consequences than if the pit had been on the river side, and sometimes even makes the former position of the levee untenable.

A. T. PARSONS.

Bakersfield, Calif., Jan. 17, 1912.

Composite Rails for Chicago Street Railways

Sir—In ENGINEERING NEWS of Sept. 28, 1911, the writer described a new type of composite rail, recently introduced into this country, under the trade name "Romapac." The first mile of American installation has recently been completed in Chicago and the results are of considerable interest owing to the process involving the cold rolling of rail steel, a thing hitherto regarded as commercially impracticable. Therefore it has seemed desirable to add to the original article, particularly as light is thrown on questions that arose therein. The "Romapac"

rails, it will be recalled, are hot rolled by ordinary processes in two sections, upper and lower. The one resembles an ordinary T-rail with a small head, and the other a grooved rail head with depending flanges. The upper sections are laid on the lower with joints broken and the depending flanges are crimped or rolled tightly into contact with the base.

This crimping is done cold, and the writer believes that the Chicago work is the first commercial case of cold rolling of steel containing so much carbon. The composition was as follows:

	Specification	Analysis of test piece
Carbon	0.50 to 0.60	0.58
Manganese	0.60 to 0.90	0.65
Phosphorus	Not over 0.04	0.023
Silicon	Not over 0.20	0.0135

In fact, when from 0.40 to 0.45% of carbon was specified for the Leeds rails, such a noted authority as Arthur Cooper of the North-Eastern Steel Works (Middlesbrough, England), stated that the ⅜-in. flanges could not be successfully bent if the steel contained over 0.30% of carbon. A similar opinion was expressed by the experts of the Phoenix Steel Works of Sheffield, England. The successful cold crimping of flanges over one-half inch thick, containing 0.58% of carbon, may therefore be regarded as an entirely new departure in steel working.

The machine for crimping on the rail heads is equipped with the rolling mechanism shown in the accompanying figure. It consists of three hard-steel rollers which press the head flanges around the lower section. The metal of the flanges flows into a wavy form at the first application of the rollers and then flattens out, about eight passes being required to complete the process.

The thickness of the flanges, measured on test pieces cut out of the finished track, was as follows:

Lip of flange..... 0.530 to 0.533 in.
Head of flange..... 0.512 to 0.525 in.

These flanges were bent through an angle of about 40°.

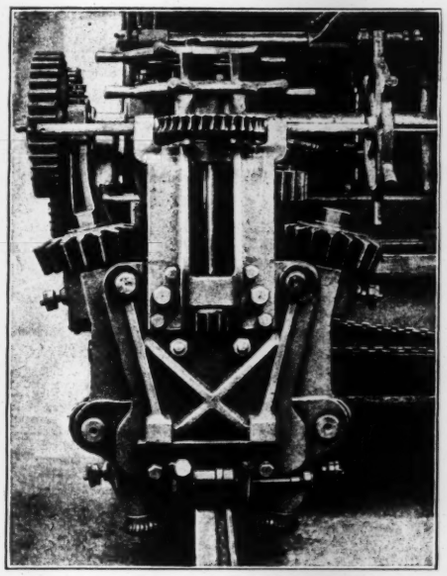
A piece of finished rail, chosen at random, was removed from the finished track and sent to Robt. W. Hunt & Co. to be tested. The following report was received:

The 12-in. length of rail was set with the direction of rolling vertical between the crushing heads of our Riehle testing machine, which operates vertically. The base section was supported on the bed of the testing machine and the load applied upon the head section alone. The center of bearing on the head section was made as close as possible to a position directly above the center of bearing on the base section.

The loads were increased slowly in the conduct of the test. The measurement of the slip was measured between center-punch marks upon the web of the base section and the flange of the head section. A log of the observations accompanies this.

In addition to the mechanical tests, measurements of electrical conductivity were made. These showed that the completed rail has less resistance than a solid rail of the same cross-sectional area. In other words, the resistivity of the steel itself is sufficiently low to more than counterbalance the resistance of the joints, even without electrical bonding.

The following letter from Mr. E. Rhodes, of London, the engineer in charge of the Chicago contract, gives the actual figures obtained by test.



ROLLER HEAD OF CRIMPING MACHINE FOR COMPOSITE RAILS

Dear Sir—The following comparative tests were made during the progress of the construction in Chicago and communicated to me (dated Dec. 16, 1911) after this track was completed:

Joint resistance of base and head sections, considering sections in parallel, per 1000 ft.	0.003478
After track is laid, per 1000 ft. without any welding	0.004485
Resistance Chicago Standard 129-lb. rail	0.007040

These tests show that the unwelded "Romapac" rail as laid in Chicago has 57% more conductance than the standard 129-lb. rail. As only 23% is due to the large section of the Romapac rail, it follows that any decrease in conductance of the Romapac rail due to the unwelded joints is more than compensated by increase in the conductivity of the rail metal, and that such net increase is about 34%.

(Signed) E. Rhodes.

Jan. 8, 1912.

Why the resistivity of these particular rails should be less than that of other rails of the same composition has not yet been determined, but in the writer's opinion, the reason is to be sought in the peculiar hot rolling to which these rails are submitted. In an ordinary rail, a large proportion of the head receives the pressure of the rolls obliquely, whereas here every part receives the full pressure direct. The result is that, in ordinary rails, the grain of the steel is coarser at the center than at the edges. An etching of a "Romapac" rail shows no such differences. Except for a skin, about $\frac{1}{16}$ in. thick, the grain is uniform throughout the section, and is unusually fine. It is not improbable that the high electrical conductivity is due to this circumstance.

W. A. DEL MAR.

Grand Central Terminal Bldg.,
70 East 45th St.,
New York City.
Jan. 20, 1912.

MECHANICAL TESTS OF COMPOSITE RAIL

Loads Applied, Pounds	Inches between Center Punch Mark	Slippage, Inches	
0	6.01	0	
10,000	6.01	0	
20,000	6.01	0	
30,000	6.01	0	
40,000	6.01	0	
50,000	6.01	0	
60,000	6.01	0	
70,000	6.01	0	
72,330	5.98	0.03	Accompanied by a loud report.
66,440	5.97	0.04	
59,320	5.94	0.07	Accompanied by a second loud report.
55,000 to 57,000	5.88	0.13	
48,000 to 52,000	5.79	0.22	Accompanied by six repeated reports.
49,000 to 50,000	5.60	0.41	Accompanied by 12 repeated reports.
49,000 to 50,000	5.43	0.58	Accompanied by continuous or intermittent reports.

Free Highway Engineering Again

Sir—I have read the various articles and letters regarding free highway engineering by the government with considerable interest and some amusement. It occurs to me that both sides to the controversy have overlooked the one great and important fact that in the Middle West, at least (and I venture the statement is fairly applicable to the United States in general), there has been and is little or no highway engineering done by engineers in private practice. Such engineering as has been done has usually been by the engineering departments of cities, or park boards, who have at times called others in consultation; or it has been the "free engineering" (see advertisement of almost any bridge concern) of the firm who furnished or erected the steel.

The result has been that on country highways large sums have been spent for poorly designed bridges put up on insufficient foundations, soon to be replaced with other bridges and they in turn by other equally poor bridges and the bridge engineer or any other engineer has received not one dollar of the whole amount.

Of course ENGINEERING NEWS and the "consulting engineers" who are afraid the government is going to put them out of business will agree with me that this is poor business, but neither

ENGINEERING NEWS nor the consulting engineers have done anything to better it. It is true that from time to time ENGINEERING NEWS has published excellent articles on highways and the importance of engineering supervision; but these have been read by engineers, not by the public or even by county boards.

The now defunct "League of American Wheelmen" did more in its day for good highways than ENGINEERING NEWS or the engineering societies have to date, for the simple reason that it got to the people who had to use and to pay for highways.

On the other hand, to my personal knowledge the government has carried on a campaign of education in the interest of good roads for over 20 years. This has consisted of lectures, pamphlets of instruction, and superintendence of construction of experimental sections of highways. Among those of which I can speak personally, Illinois and Kansas have a state department which is doing and has for some time done just what the government offers to do. Missouri, a few years ago, created the office of county engineer, the county engineer and county surveyor usually being one and the same man. About a year ago the state engineer of Nebraska was authorized to furnish plans and supervision when called on. This may not result in the best engineering practice, but it will certainly be in general enough better than no engineering to pay good interest on the investment.

If there is any consulting engineer west of the Allegheny Mountains who has done in the past enough highway engineering, in the proper sense of the term, to pay office rent, I should like to have his address.

From 1901 to 1909, inclusive, the writer was in charge of heavy railway construction in Missouri, Arkansas and Iowa, involving crossings of all kinds and sizes. In only one instance was the state or county represented by an engineer. He was a county engineer appointed under the then (1909) recent law of Missouri creating that office.

The Middle West is reputed to have the best natural roads in the country; but the best natural roads are not good enough for present needs. To get better ones we need more and better engineers in charge of them. The public does not realize that constant and rigid inspection of construction is as important as good design, and that the designs of even the best contractors need competent checking.

To date the Government Bureau of Public Roads is the only organization which has made it a business to educate the public on this point. My judgment is that actual demonstration as proposed is the best way to do this, and that the free bridge engineering of the department (paid for by the taxpayers in general) will be much cheaper than the free bridge engineering furnished to date by the structural companies (paid for now by Tom, later by Dick, and then by Harry counties, but paid for in the long run by the public in general). Not only will this be cheaper and better than past methods, but it will create a demand for the engineer not in government employ, that is now to all intents and purposes absolutely lacking. The field is there, but the engineer who attempts to work it now will have more than the usual period of starvation before him. If ENGINEERING NEWS or any of the knocking engineers can "beat the government to it" in creating a demand for engineering services that is willing to pay for those services, I for one say "you can't begin any too soon."

J. N. BRIDGMAN.

Station A,
Lincoln, Neb.
Jan. 12, 1912.

[Apropos of the general discussion concerning "free engineering work," a correspondent forwards us a circular letter issued by the publisher of a cyclopedia of engineering. We quote from the letter as follows:

> We guarantee that our "Cyclopedia of Civil Engineering" will enable you to handle promptly and efficiently the many different problems that make up your daily work.
>
> Any problem so peculiar to your special line that the cyclopedia does not quite cover it, will be handled for you free, by one of our engineering experts, through the consulting service included with each set of books.

This reminds one of the "colored chromos given away with every pound of tea." The distribution of such chromos, however, does not affect the demand for paintings by the great masters.—ED.]

Engineer and Contractor

Sir: Mr. Lindenthal's recent articles in ENGINEERING NEWS on the history to date of the Quebec Bridge undertaking are a valuable contribution to engineering literature and to general information; clear in narration, straightforward and admirable in comment.

It is kind of your correspondent in the issue of the 21st ult., Mr. Daniel B. Luten —an engineer, if we are to believe his own statements elsewhere between your covers—to hold a brief for the contractor, as distinguished from the engineer. But is not Mr. Luten somewhat self-contradictory? His idea where, in these piping days of more substantial things, such items as honor and dignity stand in the scale of values is definite. And yet he bespeaks for the contractor a share "if only in some slight degree" of these very subordinate considerations.

Engineers generally will hardly agree with Mr. Luten, in several things. They will not readily entertain the idea that it is difficult to say whether a given engineering work which failed was sound or not in design. The question in fact presses, what does an engineer look like in Mr. Luten's mental vision?

If an engineer is not competent to design and specify what will do the required work the purchaser should not employ him. If the engineer cannot do his part well enough to save the purchaser the additional cost entailed by requiring the contractor to guarantee the engineer's design he should not be retained. In this connection it must be admitted that it is sometimes difficult for the unwitting purchaser to select an engineer. But has not the ordinary man similar difficulty in selecting a physician or a lawyer? Let the purchaser once arrive at appreciation of the value of independent engineering service and his difficulty in this respect will largely disappear.

There are good engineers, plenty of them with exceptional ability, among contractors. It may readily occur that the purchaser with definite requirement gets as good value as he could in any way, in honest competition among contractors. Let it be stated at once that engineering development in many directions has been largely due to such competition and that this is particularly to be said of American bridge building. There is still the conception, however, not limited to themselves, of independent engineers, who execute engineering works without other pecuniary interest therein than their professional fees; men charged with getting the greatest value, all things considered, for the least expenditure. On any large engineering works it is self-evident that engineering advice independent of profit in the execution is essential to the purchaser. Consideration of money or of profit is not necessarily sordid; but to subject an engineer, a judge between interests, often if not generally conflicting, to a money guarantee, as Mr. Luten by implication requires, is absurd and would defeat its own object. The idea is on a par with requiring a guarantee from any law-court judge that his sentence will be just.

The Canadian Government has no abstract interest in nor obligation to engineers, nor has any other government, nor has society in general. The engineer's sole claim, the same as anyone's, to consideration is that he must be of service. Society owes him nothing unless he can repay. That he can do so, as independent engineer, as arbiter between the one who requires work to be done and the one who does it for profit, there is increasing evidence with the advance of civilization.

One of Mr. Luten's concluding sentiments is that the contractor should hold the purchaser's interests "paramount to all others." This is fine, as sentiment; otherwise it is paramount nonsense.

W. H. BREITHAUPT.

Berlin, Ont., Jan. 10, 1912.

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Engineering News

Low Temperatures and Failures of Engineering Structures

The low temperatures which prevailed over large areas of the United States during the first two weeks of 1912 were responsible for a few serious failures and many minor difficulties with engineering works. Probably the total injury caused by a large number of relatively unimportant accidents would far exceed the loss from the more striking failures.

Two notable accidents due to low temperatures are described in this issue. We refer to the standpipe failure at Sheboygan, Wis., and to the serious interruption, but not complete failure, of the water supply of St. Louis, Mo. The latter was due to an influx of floating ice from the river through the intake tower and tunnel of the water-works. The amount of this ice was so great as to break down first one and then the other of the two ice elevators which are used to keep the wet well at the pumping station clear of ice. Heroic measures were necessary and the rapid installation of a clam-shell dredge bucket to clear the well from ice, together with a change in the river level, soon restored normal conditions.

The accident emphasizes the need for a second water-works intake and possibly other precautions at St. Louis. The accident was rendered all the more serious by the fact that cogulation and sedimentation of the water supply had to be suspended, while the water supply was cut off or throttled. St. Louis was thus given an object lesson as to the conditions which prevailed during the many years in which the muddy Mississippi river water was pumped directly into the mains. Prompt warnings to "boil the water" put sensible people on their guard during the brief period that coagulation was suspended, and very likely contributed materially to reduce the dangers from possible polluted water.

The Sheboygan failure illustrates anew the possible dangers when an ice case and cap form within a standpipe. A sufficient number of standpipe failures from ice have occurred in the past to put water-works superintendents on their guard in extremely cold weather, one would think. We do not mean to assert dogmatically that the Sheboygan wreck could have been averted by watchfulness, but the possibility seems worthy of investigation—even if it would be a case of locking the barn after the horse is stolen.

It will not be amiss to call attention here to the summary of the causes of standpipe accidents and failures compiled by Prof. Wm. D. Pence and published as long ago as our issue of May 24, 1894. The summary was accompanied by a searching analytical discussion of the phenomena of failures due to ice in standpipes, which is well worth the careful attention of anyone interested in the subject and not already familiar with Professor Pence's review. The study and many other data and conclusions were reprinted in a small book entitled "Stand-Pipe Accidents and Failures," unfortunately long since out of print.

Sewer Explosions in New York City

"Out of sight, out of mind," runs the old proverb. We venture to say that if the taxpayers in our cities knew what engineers in charge of sewer maintenance know, there would be a very different attitude toward municipal ordinances to prevent the discharge of improper materials into the sewers.

Within the past month there have been two serious explosions in the sewer system of New York City, and such explosions have been going on, more or less frequently for years. Whenever one of these explosions occurs, the public is duly impressed with the risk to life and property caused by heavy manhole covers flying high in the air, but hardly a thought is given to the effect of such explosions on the sewers themselves.

No sewer is ever designed to withstand an internal pressure of any amount. It may indeed sustain such a pressure with little apparent injury at the time because of the support to its walls given by the surrounding earth; but no matter how honestly a sewer trench may be back-filled, there will almost certainly be occasional soft places which can yield slightly. An explosion in a sewer of sufficient violence to send a heavy manhole cover as high as the roofs of adjacent buildings must exert an internal pressure of several pounds per square inch. The damage will seldom show on the street surface, but such a pressure will find any soft places around the sewer, and more or less displacement cracks and breakage of the sewer wall may be expected. Through these cracks sewage may percolate to the ground outside, or the ground water may seep into the sewer. In either case, more or less loosening and disturbance of the soil around the sewer will result from this percolation with resultant risk of a cave-in.

All this is going on under the surface of the street unseen and unknown, unrealized often even by the engineers who are in charge. Some day, however, it may happen that the pavement will settle or excavations in the vicinity will reveal the unstable condition of the sewer. Taxpayers Associations will investigate the matter, and condemn the engineer who built the structure for its insecurity and the contractor who did the work for doing a poor job in packing the material around the sewer!

It is another repetition of the old story. The engineer builds an honest and solid piece of work, a road or a water main or a sewer. The public which owns the work fails to provide for its proper maintenance, subjects the road to a traffic it was never designed to carry, allows the water main to be destroyed by hidden electrolysis and permits acids and explosives to be discharged into the sewer with no thought of the consequent results. About the only comfort of the engineer is that while he may get the blame, the taxpayer will have to foot the bill in the end.

The Heating and Ventilating of Public Buildings

It is only within the past generation that the public has been educated to the point of demanding proper ventilation of schools, hospitals and other public buildings. It would be a pity if persons in authority should be misled into favoring a relapse to former conditions. Just such a mistake has come to light in New York City in an apparent attempt to discredit the work of heating and ventilating engineers and condemn without discrimination artificial ventilation in public buildings.

The trouble began with the making of charges that New York's public schools are unhealthful, due to poor ventilation. These charges were followed by others to the effect that open windows gave better ventilation than fans and air ducts, and these in turn by claims that Nature's free air was in some way vitiated and rendered noxious by being heated and passed through ducts. The fact that some physicians joined in the complaint gave more weight to the movement; and in the discussion at the recent meeting of the American Society of Heating and Ventilating Engineers, it was brought out that the ventilating systems at some hospitals have been put out of use, and new hospitals have been built with no provision for ventilation other than that afforded by opening windows.

For a clear understanding of the subject, it is necessary to distinguish between the two distinct questions involved. In the first place, there is the matter of standard conditions for healthful ventilation. It was emphasized, in the discussion before the Heating and Ventilating Engineers, that medical authorities have not agreed upon any standard condition of the air as the most healthful, nor have they set any limiting conditions beyond which unhealthful effects are to be expected. But the charges which started the discussion were only to the effect that the heating and ventilation of the schools is not up to present standards—as determined by the comfort and sensibilities of normal persons entering the building. This question of the inadequacy of the plants, as installed, to do what their designers intended should not be confused with the question of the sufficiency of those intentions.

"Your schools are not properly heated and the air in the schoolrooms is foul." This is the charge, and it does not lead toward a solution of the problem to say, "Well, it has not been decided what are the exact conditions of temperature, humidity and perhaps something else which are best for conserving health." Each question merits investigation but nothing is gained by confusing them.

If the heating and ventilating plants in the New York schools are not giving proper results, it is due to one of two things—either the plants themselves are not properly designed and built or else they are improperly operated. If the trouble is with the design or construction, it is due either to incompetence of the designer or to inadequacy of the sum appropriated for installing the plant. A competent engineer today can design a heating and ventilating plant that will give satisfaction, as far at least as concerns personal comfort, but such a plant requires money for its purchase and installation. In the distribution of funds, there is apt to be a tendency to slight the heating and ventilating plant, the unseen "works" of the building, in favor of the decorative features. On the other hand, if the trouble is with the operation of the plants, the remedy is to either replace the present operatives by others more competent, or to secure the same end by educating the present incumbents.

It should be no very difficult matter to find out, by a careful investigation of each building, just which of the causes named or what combination of causes was at the root of the trouble. In advance of such an investigation, the general abandonment of ventilating plants and a return to the open-window method, as seriously suggested by some, would be a fatal mistake. Professor Winslow at the meeting last week aptly compared it to a suggestion that each man should dig his own well and that modern water-supply systems should be abandoned, because they sometimes fail.

Who Should Own the Water Power at the Troy Dam?

We reviewed in our issue of May 18 last, the interesting controversy between Governor Dix, of New York, and the federal authorities, concerning the control of the water power developed at the dam across the Hudson River at Troy, the head of navigation.

This week there is recorded the conclusion of this controversy, and some incidental light is shed on the subject by the presentation of a report on water conservation in New York by a special committee of the legislature, which has been investigating this subject for a year.

The present dam at Troy was built by the state government many years ago as part of the state canal system. For ten years the New York state authorities have been urging upon Congress the improvement of the upper Hudson River by federal appropriations, so that it should furnish an ample waterway for the vessels using the New York Barge Canal when that shall be completed.

In June, 1910, Congress passed the desired appropriation providing, in accordance with the request of the state, for the construction of a new lock and dam at Troy about 1400 ft. above the present state dam, which is to be removed. It was required in the law, however, that "all existing water-power rights or privileges affected by the improvement must be extinguished by the State of New York," and also that the federal government should have the right to lease the surplus water power created by the new dam.

It should be said that both these stipulations are in accordance with the general policy adopted in the River and Harbor Act of 1909, which ordered that in future all engineers' reports on navigation improvement, should provide for the development and utilization of water power "in order to lessen the cost of such improvements and to compensate the Government for expenditures made in the interest of navigation."

As recorded in our issue of May 18 last, the New York State authorities took action in accordance with the federal law. The leases for the use of surplus water at the Troy dam were canceled in November, 1910, and the U. S. engineers prepared to go ahead with the Troy dam.

But the water-power concerns which had long benefited from the use of the surplus water at the Troy dam were not content to let their valuable privilege lapse without a struggle. How valuable it was, the report of the New York Water Power Committee gives testimony. It states that the use of the surplus water at the Troy dam was originally leased for $550 a year and the lessees actually develop 3000 to 6000 continuous horse-

power. Naturally the users of this power were doubtful of their ability to make an equally good bargain with the federal engineers for the use of the surplus water at the new dam.

On Jan. 1, 1911, a new state administration came into power in New York and shortly afterward endeavored to annul the action of its predecessor on the Troy dam matter. Attorney-General Carmody rendered an opinion that the lease of the surplus waters at the State dam was a lease in perpetuity and could not be annulled. Governor Dix requested the federal authorities to delay work upon the new dam until Congress could pass on a proposal to have the State construct the Troy dam and lock with its own funds. A similar scheme is set forth in the annual report of State Engineer Bensel just issued as follows:

> It is hoped that in the near future the work of constructing the Troy Dam may be undertaken by the state, and thus preserve for the benefit of the people the water which will be collected by the dam and which will not be needed for purposes of navigation. I am of the opinion that the state should construct this portion of the canal system in accordance with the vote of the people and thus secure the control and operation for the benefit of the people of not only the lock, which will be the throat or entrance to all of the state canal system, but also the water which will be available for power.

Nothing was done by the state authorities toward securing from Congress a revision of the law, however, nor was any action taken by the state legislature for the construction of the dam with state funds.

Under these circumstances Secretary of War Stimson has ordered work on the new Troy dam to proceed without farther delay. It is altogether probable that the attempt of the New York State authorities to cancel the annulment of the lease of the surplus waters at Troy and the contract with the federal government entered into by the previous state administration is invalid. Further than this, the federal courts have decided that water power created as an incident to a navigation work carried out by the federal government, is under the exclusive regulation, control and disposition of the federal government.

There is no question involved in this as to whether the value of a water power as a gift of nature should accrue to the benefit of the people of the nation as a whole or of the state in which it is located. There is no such question here; because the cost of the dam will be so great that the water power developed is little likely to yield enough to more than pay interest and maintenance charges on the structure.

Further than this in a published letter to Gov. Dix, Secretary Stimson says:

> I am willing to say further that, while in my opinion the United States will be the owner of all of the water power which may be created by this improvement to navigation erected by the United States, nevertheless, in case the amount of the water power thus produced shall eventually prove to be more than sufficient to pay reasonable interest and sinking-fund charges upon the expenditures made by the United States in this improvement, I see no objection to the United States collecting and turning over the proceeds of any surplus beyond such amount to the State of New York for the benefit of the people of the state.

In view of the fact that for many years past the State of New York has been practically giving away the surplus water at the Troy dam, the taxpayers of the state may congratulate themselves that the new dam is to be built with federal funds instead of state funds; nor are they likely to expend much sympathy upon the water-power interests at Troy which have been enjoying a princely revenue from the power created by the state dam all these years.

It should be clearly understood that the question here discussed is entirely separated and apart from the question as to the rights of the public in water power developed by private enterprise. As has been fully set forth in these columns, the competitive conditions are such that water power development by private capital in most localities and under most conditions is involved in large risk and often results in loss to the investors.

Entirely different conditions are presented, however, where water power is developed as an incident to the improvement of navigation. There can be no dissent by any reasonable person from the statement that when a dam is built by the nation or by a state to improve navigation, or by a city or an irrigation district for water storage, the owner of the dam ought to own also any water power created by its construction.

But in very many cases this valuable asset has not been handled for the benefit of the taxpayers who furnished the money for the dam but has been diverted to private parties.

Most illuminating on this point is the report of the New York legislative committee on Water Power conservation. It is not merely the fact recorded in that report that the surplus waters of the old Erie Canal were originally leased to private users at what seems now a nominal figure. It may well be that at the time these water powers were leased, some 80 years ago, the price was a reasonable one. Nor is it so strange, either, that these original leases should not have been disturbed during all these years. It is only within the last fifteen years, since the development of electric transmission that water power has acquired large value. What is little short of amazing is that in the development of the plans for New York's hundred million dollar Barge Canal, with all its enormous possibilities in the way of water-power development—plans which were made at a time when the value of water power was perfectly well known to the public and to all engineers—practically nothing was done toward the development of the incidental water power in a way that should yield a large revenue to the state. Nor has anything effective been done to the present time for the development of this power on a large scale.

It is perfectly true that the navigation improvements hitherto made by the federal government have likewise taken little account of the possible revenue from water power; but as noted above, a radical change has now been made in this policy. We can even look forward to the time when the value of water for power will be seen to be superior to its value for navigation, and when the work of river control will be undertaken with a better balanced appreciation of the value to the public of water for different purposes than now obtains.

The report of the New York Committee on Conservation of Water Power, which is abstracted at length in this issue, lays down a plan for carrying out a broad policy of water-power development under state authority which promises far greater benefit to the state, in our opinion, than all the expenditure made by the state in connection with its inland water-way system.

Finally, it seems to us that this neglect of the State of New York during more than three-quarters of a century to reap adequate returns from the water powers created by state funds is an object-lesson worth the attention of our Socialist friends who wish to see all property and all industrial activity concentrated in the hands of the state or of great trust organizations. It is not necessarily outright dishonesty that caused New York State to allow the valuable water power of its canals to be used by private parties for a mere pittance. Neither is there necessarily dishonesty on the part of the federal government authorities who have allowed similar conditions to obtain in connection with federal navigation works. Both cases illustrate the great difficulty in securing from any governmental body the same intelligence, economy and efficiency that the private individual gives to his own business. And what is true of the state and federal governments and of our large municipal governments, is true also in somewhat lesser degree of many of the huge corporations of the present day.

Those who see behind the scenes of some of these organizations know something of the waste and mismanagement that goes on, of the lethargic conservatism that rules at one time when enterprise and willingness to take risks ought to prevail and of the mistaken judgment, which at another time causes money to be lavished on schemes which never return a profit.

Water-Power Projects in New York

The New York State special committee appointed to investigate the subject of water storage and water-power development in the state has just reported to the Legislature. An abstract of that report is here given.

The New York Legislature of 1911 created a special committee to investigate the subject of water storage and water-power development in the State of New York. The report of this committee was presented to the legislature on Jan. 29 and forms a notable contribution to the subject of water conservation.

The committee has had the benefit of the work done by previous bodies, which have been dealing with this problem in the State of New York, to wit: The Water Storage Commission of 1902, the River Improvement Commission of 1904, the Water Supply Commission of 1905, and its successor, the State Conservation Commission of 1911.

New York has a larger amount of water-power in use than any other state, the total estimated development in 1911 being 800,000 hp. This represents a remarkable growth since 1890, when only 233,000 hp. had been developed. Notwithstanding this growth, there is in the state more water-power undeveloped than that already utilized. The committee estimates that apart from possible water-power developments of enormous size on the Niagara and St. Lawrence Rivers, over a million additional horsepower of water-power may still be developed on New York rivers.

To provide such an increased power, however, the flow in the rivers must be regulated by the construction of storage reservoirs on the head waters; and the committee takes strong ground in favor of such reservoir construction. It declares that the work must be done by the state, since the experience of the past 16 years has demonstrated that private owners of water-powers and water-power sites and others who would gain benefit from flood-protection works cannot be brought together and made to carry out these works in coöperation.

New York is in a different position from any other state with respect to water-power development because of her great canal system, still owned and operated by the state, while the canals which once existed in a number of other states have nearly all been abandoned.

In developing the water-supply of this canal system, surplus water was made available for power development at many points. Leases were made to private parties for the use of this surplus water at the time the canal system was built in 1828 and 1829. The prices then fixed have ruled ever since, except that the state authorities have in recent years annulled many of the old leases, although the private concerns have gone on using the water.

As an illustration, the committee cites the case of the surplus canal waters at Lockport which were originally leased for an annual rental of $200. The owner of this lease, the Lockport Hydraulic Co., has for many years been developing 3400 hp. at this point. For another illustration, the water-power at the Troy dam was originally leased for $550 a year, and 3000 to 6000 continuous horsepower is actually developed at this point.

The average annual rental received by the state for all the surplus waters of the state canals during the 85 years it has been supplying these surplus waters to power users is the paltry sum of $2256. In recent years, the Canal Board has canceled many of these old leases, so that instead of furnishing the water for a nominal amount, the power owners get it for nothing. In 1911 the total income of the state from all the surplus waters of the state canals was $210! The committee very pertinently says:

> But while many of these leases have been canceled, the water still flows where it did before, and no disposition of the surplus value has been made by the state. Its force is being utilized by the holders of the leases or their successors in interest, but no revenue to the state is being derived therefrom.

It is a remarkable illustration of the unbusinesslike methods with which government is too often conducted, that through all the political changes and the good and bad state administrations of the past 85 years, this conversion of state property to private use at a nominal rental has been allowed to continue unchanged, with a resulting loss of many millions to the state's treasury.

Again in the making of plans for a water supply for the new Barge Canal now under construction, the committee says that "no thought was given to the possibilities of power development as a useful by-product." It is possible that some of the promoters of the Barge Canal scheme had their own reasons for wishing the state to make no plans for developing power from its surplus waters as a by-product.

As to the possibilities in this direction, the committee says:

> According to present plans and without extra outlay on behalf of the state, it is apparent that more than 100,000 hp. will be developed from the use of the surplus waters not needed in the navigation of the Barge Canal, or from those waters after they have fulfilled their uses in relation to navigation; and if the construction were carried on with a view to the development of hydraulic power, this amount would be greatly increased.

By way of illustration, the committee cites conditions at Rochester where it estimates that by using the summit level of the Barge Canal as a source of supply, 25,000 hp. could be developed for 24 hr. per day and 365 days in the year. At $10 per hp. per annum this would yield to the state an annual revenue of $250,000.

Turning now to water-power development on the Niagara and St. Lawrence Rivers, the committee urges that any further taking of water from the Niagara for power development should be made to yield a revenue to the state, and that the same course should be pursued with respect to projected power development on the St. Lawrence. Quoting from the committee's report:

> We believe that in the interests of conservation these great water powers, the title of which in the people of the State of New York cannot be questioned, should be carefully guarded and no permits or franchises issued in the future that do not recognize and protect the rights of the citizens of the state in the form of an adequate compensation for the value of the franchise conferred.

Turning now to other proposed water-power developments of magnitude through the provision of storage reservoirs, the committee reviews separately the projects for great reservoirs on the Sacandaga, the Genesee, the Black, the Raquette and other important rivers of the state and discusses at much length the legal questions arising from the ownership of the power sites by riparian owners.

In order to carry out a number of these projected developments, amendments to the State Constitution are necessary which will permit the flooding of tracts in the Adirondack forest reserve. Estimates show that about 30,000 acres of forest land would be flooded by all the reservoirs thus far planned.

After considering at length the work undertaken by the Province of Ontario in the distribution and sale of electric current by the provincial and municipal governments, the committee says:

> Your committee believes that whatever water power is developed by the state, as is recommended by this report, should be sold at current market rates and not in competition, and that the revenue so derived should be used for lessening the burdens of taxation of the people. We further believe that wherever conservation of water results in the development of water power belonging to riparian owners, the state should derive a revenue therefrom for the additional waters thus furnished.

The difficulty which has thus far prevented the carrying out of the important projects for water storage in New York is the difficulty of apportioning cost and securing united action among the riparian owners affected and the difficulty of securing state construction of works which would chiefly benefit private concerns. The committee reviews the various legal obstacles which have hitherto blocked action and presents a plan for overcoming them, as follows:

The state has at great expense made accurate surveys and determined the conditions surrounding two great projects of conservation of water that have been put forward during the last 16 years. These are the improvement known as the Sacandaga improvement (the upper Hudson) and the improvement of the Genesee River. Your committee deems it of prime importance to see if a plan cannot be devised that would result in the immediate carrying out of these two projects.

We desire to lay before the legislature two plans of procedure which, in our judgment, would result in the immediate construction of reservoirs and the conservation of these great resources, which are now being wasted. These two plans we have denominated for convenience the "Tax on Water Impounded Plan," and the "Sale of Water Plan."

THE TAX ON WATER IMPOUNDED PLAN—In order to carry out this idea, it will be necessary to organize a quasi public service company, which shall be operated without profit, but in the public interest, which company we shall hereafter call the "Improvement Company," and the charter of which shall contain the following provisions:

(1) Power to develop, impound, buy and sell water for municipal, sanitary, stream regulation and power purposes.

(2) The right of eminent domain, including the construction of water pipes and necessary electrical transmission lines.

(3) All dams to be built according to plans of the state authorities and under their supervision.

(4) That such company shall be subject to the jurisdiction of the Public Service Commission:

(a) As to rates charged for water and for electrical energy.

(b) As to amount and nature of securities issued.

(5) That before any bonds are issued and before any actual construction work is undertaken there shall be disposited with the Conservation Commission contracts between the Improvement Company and beneficiaries for the sale of water, the aggregate income from which contracts shall be at least sufficient to pay:

(a) Interest on the cost of the improvement.

(b) The cost of maintenance.

(c) A sum sufficient to amortize the cost of the improvement within a period of 50 years.

(d) The charge of the state for the impounded water.

(6) That all contracts for the use of water shall release to the Improvement Company, or to its assignees or successors, the rights of riparian owners to so much of the flood waters of the stream as are necessarily impounded for the proper regulation of the flow of the stream.

(7) That the duration of the corporation shall be 50 years.

(8) That the corporation shall be required to pay into the state treasury annually a charge for each 1,000,000 cu.ft. of water capacity of the reservoirs constructed.

(9) At the end of the period of 50 years the entire right, title and interest to and in the lands, structures and waters shall vest in the state.

The capacity of the proposed Sacandaga Reservoir is 32,000,000,000 cu.ft. of water. If a charge of $5 for each 1,000,000 cu.ft. of water capacity of the reservoir constructed were required, it would result in an annual income to the state of $160,000.

The capacity of the proposed portage reservoir at the head waters of the Genesee is 19,000,000,000 cu.ft. of water. A charge of $5 for each 1,000,000 cu.ft. of water capacity of the reservoir constructed would result in a net income to the state of $95,000.

The "Sale of Water Plan," proposed by the committee differs from the "Tax on Water Impounded Plan" in that the state itself is to build and own the reservoirs and other works, the money for construction being furnished as before by the quasi-public service "Improvement Company," organized as just described.

The conclusions reached by the committee are finally summarized as follows:

Your committee believes:

(1) That so far as the state owns water or water rights, the same should be conserved and developed to the maximum point of commercial efficiency, and that so far as such rights are owned by individuals, every encouragement should be given for their development.

(2) That no further grants of water-power privileges or rights to water, the ownership of which is clearly in the state, should be granted except for limited periods and upon provision being made for adequate compensation to the state.

(3) That where grants have been made by the state of valuable water rights which, by their terms, are revocable, such grants should be revoked, in order that the state may enjoy the maximum benefit from its property, but that where the grants of the state have been made absolute and without any provision for their revocation, such rights should be regarded as sacred and inviolable.

(4) That the various watersheds of the state should be improved, and that at the head waters reservoirs should be constructed, where commercially practicable, for the impounding of storm waters, so that the flow of rivers may be regulated.

(5) That in the enactment of any laws relating to the construction of storage reservoirs for the conservation of water the following principles should be observed:

(a) The state, as such, should derive a revenue from such undertaking, thereby lessening the burden of general taxation.

(b) All reservoirs for the impounding of water should be constructed under state supervision and control and according to plans and specifications prepared by the Conservation Commission.

(c) Whenever reservoirs are constructed for the impounding of waters, they should be of a capacity ample to regulate properly the flow of streams so as to produce as near a uniform flow throughout the year as possible, and the ownership of such flood waters necessary for such regulation should be in the state.

(d) No improvement of a watershed should be undertaken or property acquired therefor until there have been deposited with the Conservation Commission either the funds necessary for such purpose, together with contracts for the payment of some profit to the state, by parties to be benefited, or contracts for the use of the water so impounded sufficient to yield an annual income to the state at least equal to a sum sufficient to pay interest, maintenance and amortization charges, together with some profit to the state.

(e) All contracts for the use of the waters so impounded should provide for the release by the users of all title to so much of the flood waters as is necessary for the proper regulation of the stream flow.

(f) All contracts for the use of water should be made for a term of not to exceed 50 years, and should be subject to the paramount necessities of navigation and the rights of municipalities to acquire such waters for the uses of their inhabitants.

The committee which has carried out this important work had as its chairman, Senator T. Harvey Ferris. Its counsel was Arthur J. Baldwin, Esq., of New York City, and its engineer was Harvey N. Latey.

Motor Trucks equipped with a hydraulic variable-speed transmision are now on the market. A five-ton truck of this type is built by the American La France Fire Engine Co., of Elmira, N. Y. It is driven by a four-cylinder, four-cycle gasoline engine of 48 rated horsepower. The hydraulic transmission used is the Manly drive, which was described in Engineering News, Feb. 18, 1909. The drive, as applied to the five-ton truck, consists of a pump driven by the crankshaft of the engine and two motors applied to the differential shaft of the truck. These hydraulic motors are driven by oil supplied to them by the pump on the engine crankshaft.

The stroke of the pump remains constant, and the speed of the motor is changed as desired by varying the length of its stroke by means of a single control lever.

Power is transmitted from the differential shaft to the rear wheels by the familiar double-chain drive commonly used on other motor trucks. The use of the hydraulic transmission makes unnecessary any change gears, clutch, differential gears or service brakes. An emergency brake of the expanding drum type is provided on the rear wheels. The truck is designed for a maximum speed of 12 miles per hour going ahead, and three miles per hour on the reverse. Any speed whatever between these two limits can be obtained by means of the hydraulic transmission. This truck is being placed on the market by the Hydraulic Truck Sales Co., 1777 Broadway, New York City.

A similar truck, built by the Remington Standard Motor Co., 3 Columbus Circle, New York, was exhibited during the commercial vehicle show at Madison Square Garden.

Annual Convention of the Indiana Engineering Society

The 32d annual meeting of this society was held at the Denison Hotel, Indianapolis, Ind., on Jan. 25 to 27. The president, D. B. Luten, presided, and there was a fair attendance. Four sessions were held for the presentation of papers, one evening was devoted to the annual dinner and one afternoon there was an excursion to the new Capitol Ave. bridge, the water-works and the power house of the Indianapolis, Terre Haute & Eastern Electric Ry. The program was somewhat overcrowded, and though a number of the reports and papers were not presented and others were short, there was little opportunity for discussion. The report of the secretary showed a membership of 225. The president, in his annual address, referred to the desirability of Indiana having a highway commission and a highway engineer, and also the desirability of the city of Indianapolis adopting a building ordinance which will prevent such work as resulted in the recent failure of the Prest-O-Lite company's concrete building.

Concrete received a good share of attention. Prof. W. K. Hatt (Purdue University) described some "Tests of a Girderless Reinforced-Concrete Floor" in a Chicago building. The concrete was cut away in places to expose the steel, and measurements were made by means of plugs and extensometers. D. V. Moore presented a paper on "Practical Concrete Construction," describing the methods employed in making and placing concrete, particularly for buildings. He considered that the mixer should have a capacity of at least 18 cu.ft., and that better results are obtained by depositing concrete by gravity chutes than by wheelbarrows. He referred also to the question of surface finish for exposed surfaces, and a number of views were shown representing finish by means of colors, and by treating the surface by the sandblast, acid wash, rubbing, etc.

Following this paper, Mr. Moore presented the report of a Committee on Reinforced-Concrete Buildings, with some suggestions for a new building ordinance relative to this material. The city building inspector has drafted an ordinance, based upon the new Chicago ordinance, and has asked the society to present any opinion regarding it. In this connection, Mr. Moore referred to the ordinances published in a recent number of ENGINEERING NEWS. There was no discussion and the only action taken was to continue the committee and empower it to present suggestions to the building inspector. Some views of the wrecked Prest-O-Lite building were shown by Mr. Brossman. In a paper on "Reinforcing Steel for Concrete," by J. Olney Dean (Chicago), the manufacture of steel and steel bars was described, and particulars were given as to bars of high and low carbon steel and cold and hot twisted bars. A paper on "Oil Mixed Concrete," by Logan W. Page (Washington) showed the results of some experiments; the absorption is much lower than in ordinary concrete, but there is a reduction in the strength of the concrete and in the bond of steel reinforcement.

Several papers related to road and street paving, and in one of these, on "The Maintenance of Our County Roads," by Robert E. Gibbons (Terre Haute), stress was laid upon the uneconomical but universal practice of building good roads and paying no attention to their maintenance. The result is that these roads have only 30 to 50% of their proper life, and in many cases are in worse condition than common earth roads. He suggested that the counties and the state should coöperate to undertake maintenance as well as construction of roads. T. H. Chubb (Chicago presented a paper on "Concrete Pavements for Streets and Roads," in which he described various methods of construction with plain and reinforced concrete. These included a method in which a wearing surface of bituminous composition and sand is applied to the concrete, the composition being sprayed from a tank wagon and the sand spread in a thin layer from a long narrow hopper on a sand cart. A paper on "Bituminous Macadam Construction," by A. N. Johnson (Illinois State Highway Engineer), described very fully the different methods of building roads with this material, which is coming into very general use on account of its power to resist the disintegrating effects of automobile traffic.

The Furnas pneumatic street-cleaning machine was described in a paper by Charles A. Tripp, who stated that while flushing by water under pressure is effective, it involves an excessive use of water, is injurious to the paving and results in too much dirt being carried into the sewers. The Furnas machine, which is self-propelling, has a fan causing a powerful suction in a pipe which has a hood resting on the pavement. The current of air is discharged into a separator, where the velocity is reduced, the dirt falling into a hopper and air returning to the interior of the suction hood.

A group of papers on water supply and hydraulic engineering occupied one session. Prof. R. L. Sackett (Purdue University) discussed "Electrical Methods of Water Purification" and presented also a brief report on "Stream Pollution," stating that while improvements are barely noticeable from year to year yet a review of a term of years indicates a decided improvement in conditions. "The Pollution of the Ohio River" was treated in a paper by J. A. Craven (Indianapolis); he showed a reduction of typhoid cases at Cincinnati from 64 before the filtration plant was put in service, to 12.6 after the use of this plant. Two towns in Indiana (near the river) which take water from wells show no cases of typhoid (1910), while a maximum of 133 was reached at Vevay, which draws its supply from the Ohio. In a paper on "The Failure of Dams," Prof. Sackett referred especially to the failure at Austin, Penn., and he exhibited a number of forms of section of notable dams. A case of a dam being shifted from position by a flood, but not overturned, was cited by Chas. Brossman (Indianapolis). Prof. Gardner S. Williams (Ann Arbor, Mich.) described some low-head water-power plants on Michigan rivers, and the operation of the Indianapolis water-filtration plant was described by Harry E. Jordan. In this group of papers may be included also a lecture by Prof. W. K. Hatt on "The Panama Canal."

The committee on bridges reported that the average expenditure by the counties for bridge work during 1911 was $16,000 per county (or $1,500,000 for the state). The appropriations for 1912 average $13,800 per county. The average cost per bridge was $1755, but four county bridges were commenced which were estimated to cost over $30,000 each. Mention was made of some of the new reinforced-concrete bridges. One of these, at Fort Wayne, has 105-ft. arches and is faced with brick, with stone for the arch rings, coping, etc. The committee finds the steam rollers in use to average 22,400 lb. empty (10 hp.), although one firm builds a 25-ton machine. About 66% of the weight is carried on the rear wheels, and it is believed that many details of steel bridges are not designed for this concentrated load of 14,000 lb.

In a paper on "The Vertical Posts of Bridges," Prof. Albert Smith (Purdue University) stated that the design of compression members is very loosely defined in specifications and in practice. After an analysis of the conditions and the stresses he estimated that the latticing of these posts should be in the truss plane, in spite of the loss in pin-plate metal. Where channels are used with their webs in the truss plane a web plate should be used to connect them.

A paper on "Some New Slide Rules and their Accuracy" was read by Prof. H. A. Thomas (Rose Polytechnic), and Prof. L. McCormick (also of Rose Polytechnic) exhibited and described a new stadia attachment for transits. The requirements, duties and responsibilities of inspectors on engineering construction work were dealt with by F. O. Hodson (Gary) in a paper on "Inspection and Cost Data in Relation to City Improvements." The cost data consisted of records of work at Gary, Ind. E. G. Stradling (Lafayette, Ind.) gave a talk on an installation of automatic block signals between Indianapolis and Hammond.

Annual Meeting of the American Society of Heating and Ventilating Engineers

The 18th annual meeting of the American Society of Heating and Ventilating Engineers was held at the Engineering Societies Building, in New York City, on Jan. 23-25. The number of members and guests registered was 250. Four professional and business sessions were held—one each on Tuesday and Wednesday, in the afternoon, and two, in the afternoon and morning, on Thursday. The attendance at these sessions was from 100 to 150.

The greater part of the opening session, on Tuesday, was taken up with committee reports and routine business. The reports of the secretary and the treasurer showed that the society's financial position, while comfortable at present, was rather unstable. There was a good balance on hand in the treasury, but the expenditures for the year had exceeded the income from dues alone by an amount equivalent to $1.85 per member. Initiation fees collected from new members had saved the society from insolvency. This condition, it appeared, had prevailed for some years. The present dues for all grades of membership are $10 per year, and the membership is about 400.

The report of the Board of Governors mentioned the establishment of the society's headquarters in the Engineering Societies' Building, in New York, which was accomplished during the past year.

Committees on compulsory legislation, standards, tests and air leakage and ventilation of the closed room reported progress. The committee on heating guarantees submitted a report stating that the designer of a heating plant should be held responsible for its adequacy provided it was installed in strict accordance with the plans and specifications. The contractor should be held responsible for the quality of materials and work done in installing the plant. The practice of placing all responsibility for the success of the plant upon the contractor was condemned, because it gives the contractor a plausible excuse for deviating from the engineer's plans.

The report of the Illinois chapter told of its work in connection with the recent establishment of a bureau of ventilation in the Chicago health department.

In addition to the address of President R. P. Bolton on "The Use and Abuse of Fuel," two papers were presented at this session: "Drying Apparatus," by H. C. Russell, and "A Heat Exchange Diagram," by N. W. Akimoff, of Philadelphia. Mr. Russell's paper, which was read by the secretary, was of a somewhat elementary nature. Mr. Akimoff's paper presented in a useful form the heat-exchange diagram given some years ago by F. I. Weiss in his book on "Kondensation." The author stated that this diagram, though originally developed for use in the design of cooling towers, can be applied to the problems of treating or conditioning air so far as concerns cooling and humidity control.

The Wednesday afternoon session was devoted to the subject of ventilation. Papers were presented as follows: "Dust in Relation to Heating," Conrad Meier, New York; "Effect of Relative Humidity on Comfort and Health," J. I. Lyle, New York; "Chemical Notes on Ventilation," P. N. Evans, Lafayette, Ind.; "Ventilation Problems," D. D. Kimball, New York.

The report of the committee on heating and ventilating school rooms, which was appointed to coöperate with the ventilation committee of the American School Hygiene Association, was also presented at this session, being read by the committee chairman, Frank Irving Cooper. Attention was called in this report to the fact that no standards for healthful ventilation and air treatment have been established by medical authorities. The committee planned to make comparative trials of the effects of different humidity and temperature conditions by actually supplying air at different fixed conditions to two parts of the same school building and observing the comparative health and scholarship of the pupils. Such tests were already under way in Boston.

An extensive discussion of the general subject of ventilation followed in which the chief participants were physicians and others specially invited to take part in this meeting. The doctors, quite naturally, believed that the establishment of standard conditions for healthful ventilation was their own prerogative and some efforts were described along the line of establishing such standards.

Dr. W. Gilman Thompson, of New York, expressed the opinion that the per cent. of CO_2 (a standard now discredited, it appears, by some authorities) was a measure of healthful conditions. He knew personally of three hospitals where the effect of the heating and ventilating plants had been found to be "pernicious," and their use discontinued. He described tests made to determine the effect of foul air upon blood pressure. It was found that the blood pressure became lower in a closed but "ventilated" room than in the open air.

Dr. James H. McCurdy, of Springfield, Mass., described tests being made on a large scale in that city. A room in which 150 men took exercise was arranged so that both temperature and humidity could be regulated over a wide range. The humidity could be varied from 20% to 80%. Observations were made of blood pressure and heart rate. It was found that work was uncomfortable with the temperature below 50° F., or above 70° and with relative humidity below 25% or above 70%.

Prof. C.-E. A. Winslow, of New York, declared that faulty ventilation conditions in connection with modern ventilating plants were due largely to the failure to supply proper standards. In his opinion, the data for establishing such standards must eventually be collected by the engineer directly interested. They would be making a mistake to wait for the doctors to do this. Referring to the "latent danger of house dust" as an agent of infection, mentioned in Mr. Meier's paper, Prof. Winslow stated that the dust danger, so far as the spread of disease was concerned, was very, very remote indeed.

At the Thursday sessions, the discussion of the ventilation question was entered upon by members of the society. C. B. J. Snyder, superintendent of New York School Buildings, referred to a statement made at the Wednesday afternoon session by Mrs. Stephen S. Wise, of New York. Mrs. Wise had stated that present conditions as to ventilation and temperature were bad in some 30 New York schools which she had visited. She was inclined to place the blame on the heating and ventilating systems. Mr. Snyder announced, in significant tones, that while the department of which he has charge is called upon to *design* the public-school heating plants, it has not for some years had any control of their operation or of the coal supply. He had found bad conditions in some school buildings directly due to incompetence of the janitor or so called engineer in charge of the heating plants, but had no authority to enforce the employment of a competent operative.

It was suggested that the men engaged as janitors were generally chosen because they were no good for anything else, and a number of members recounted particular cases where the blame for poor heating or ventilation had been definitely traced to incompetence on the part of the man in charge.

President Bolton corrected the idea that dissatisfaction with and disuse of ventilating plants was confined to schools and hospitals by describing conditions in other public buildings. In the Tombs prison, in New York, an extensive and expensive fan system was not used at all, never had been used, although the foul air in some rooms was most noticeable. In the New York Hall of Records, a comparatively new building, a complete blower system had been installed, but was not used. The only fans in operation were those serving vent openings in the roof, with the result that the air supply was drawn in through any available openings. Much of it came in through the intended blower openings, but these were near the street level and no cheesecloth had been put on the screen frames. As a result, quantities of street dust were

drawn in with the air, and a large complement of cleaners found employment in the building.

The discussion was concluded with the passing of a resolution recommending that the supervision of the janitors operating heating and ventilating plants in New York public schools and the supervision of repairs and upkeep of such plants be put in the hands of the department designing the plants. It was apparently intended that this resolution should express the sense of the society that this was the proper arrangement for not only New York alone, but all other cities

Papers presented Thursday morning were as follows: "Steam Heating Large Department Stores," Davis S. Boyden, Boston; "Hot Water Heating by Forced Circulation," Ira N. Evans, New York; "Auxiliaries for Pressure Systems of Hot Water Heating," J. J. Wilson; "Steam Heating from the Receiver of the Compound Engine," Auguste Beaurrienne, Paris, France; "Ventilating a Steam Laundry," A. M. Feldman, New York.

Mr. Boyden's paper gives the results of a two days' test of the heating plant of a Boston department store, made to determine the efficiency of the boilers and to study the relation between the daily load curve of the heating plant and the electric load curve. Mr. Evans' paper was based on records of the hot-water heating plant at the Hoboken terminal of the Delaware, Lackawanna & Western R.R.

Frank T. Chapman presented an informal paper on the ventilation, or rather the lack of ventilation, of motion-picture theaters. He described existing conditions, in view of the tremendous and growing patronage of these places, as truly a menace to the public health, regarding which there is as yet little or no legislation.

Wm. Kent presented a special committee report on standards for pipe fittings and flanges. This report endorsed the standards recently prepared by a committee of the National Association of Master Steam and Hot Water Fitters cooperating with a committee of the American Society of Mechanical Engineers. These will be known as United States Standard Fittings.

At the final session, on Thursday afternoon, the following papers were presented: "Heat Transmission with Indirect Radiation," Frank L. Busey, Buffalo, N. Y.; Tests of Vacuum Cleaning Tools and Exhausters," M. S. Cooley, Washington, D. C.; "Definition of the Unit of Heat," P. P. Bolton, New York; "Heating a Swimming pool," Cesar Teran, New York.

Mr. Busey's paper explained and discussed the theory of convection with forced circulation over indirect heaters, as originated by W. H. Carrier, of Buffalo. Mr. Carrier recently set forth this theory in a paper before the December meeting of the American Society of Mechanical Engineers. Mr. Busey's paper gave additional data in support of the theory and showed its applicability to forms of indirect radiators in common use.

Mr. Bolton's paper pointed out an apparent divergence of practice in the definition of the heat unit, consisting only in some disagreement as to the temperature or range of temperature at which the heat unit was to be measured, and proposed that the society's committee on standards take this matter in hand and make some recommendation.

A discussion of "scientific management" brought out a considerable difference of opinion as to the applicability of its so called principles to the heating industry. Some of the heating contractors would admit its value to manufacturers, but were positive it wouldn't work in their own business. Its strongest advocate was one who confessed that his only experience as a manager was in advising other people how to manage.

The report of the committee on revision of the constitution, presented at a previous session, was brought up for discussion and, after some changes, was finally approved and submitted to the membership for letter ballot. The most striking feature was an amendment proposed by S. A. Jellett, a member of the committee, which reads as follows:

> The Society reserves the right by a two-thirds vote of the members present at any session of the annual meeting (provided that not less than 25% of the active membership of the Society has been registered at such annual meeting) to instruct or direct its officers on any matter or matters affecting the welfare or policy of the Society, and such instructions or directions must be carried out.

Officers for the ensuing year were elected as follows: President, John R. Allen, Ann Arbor, Mich.; vice-presidents, John F. Hale, Camden, N. J., and E. F. Capron, Chicago; secretary, W. W. Macon, 29 West 39th St., New York; treasurer, James A. Donnelly, New York. The following were elected to the Board of Governors: R. P. Bolton, New York; James D. Hoffman, Lincoln, Neb.; F. R. Lewis, Chicago; W. M. MacKay, New York; D. D. Kimball, New York.

An International Conference on peoples' baths and school baths will be held at Scheveningen, The Hague, during the last week of August, 1912. The chief purpose of the meeting is the promotion of public interest in bathing. Four sessions will be held for the presentation of papers and reports. The subject to be discussed includes technical questions relating to the water supply, planning and general arrangement, operation and cost of maintenance of public baths and school baths and the relation between public baths and public health.

Mileage and Cost of Public Roads in the United States

The U. S. Office of Public Roads has just published as Bulletin No. 41* a compilation of information showing the mileage and, in a general way, the costs of the improved and unimproved roads in the United States at the end of the year 1909. This is similar in design to Bulletin No. 32, issued about five years ago, which carried the same data up to the end of the year 1904. In order, therefore, that the progress made may be judged comparatively, the statistics given are also referred to similar figures from the previous bulletin.

The data are given by states and in most cases by counties, and each state is, in addition, provided with a text explanation of its peculiar conditions. The whole makes a work much too long to be abstracted in this journal, but we have reproduced here the prefatory statements and two tables showing the general statistics for the whole country.

INTRODUCTION

The value and need of accurate road statistics have heretofore been imperfectly understood and consequently only scant records are available in many places. The importance of complete records in regard to expenditures and cost of roads and of a stricter classification of the different kinds of roads has been brought to the attention of every county and township in the United States through these investigations.

The statistics contained in this publication relate to country roads only, except in a few instances where it has been impossible for correspondents to draw the line definitely between country roads and village streets. The term "improved roads," as used in this bulletin, implies a road which has been graded, drained and surfaced with a hard material or a combination of materials, or to which some preparation has been applied, resulting in a reasonably smooth, firm and durable surface. Macadam or gravel roads may be cited as examples of hard material applied to earth subgrades; the sand-clay road and bituminous macadam are good examples of the application of combinations of materials to effect the desired result, while the use of oil, tar and other bitumens, principally on macadam roads, though occasionally on earth roads, illustrates the improvement of a road by the application of preparations.

SOURCES OF INFORMATION—The information contained in the bulletin has been secured by correspondence, principally with road officials and partly with private citizens of the various states and territories, counties, townships, districts and other civil subdivisions of the United States. In many cases, the information was obtained from voluntary county correspondents appointed by this office for the purpose, but in almost every case these correspondents were either road officials or the

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*"Mileage and Cost of Public Roads in the United States in 1909," by J. E. Pennebacker, Jr., and Maurice O. Eldridge. Bulletin No. 41, U. S. Department of Agriculture, Office of Public Roads, Logan W. Page, Director.

best informed private citizens in road matters in their respective communities.

The magnitude of this task may be appreciated when it is understood that there are in the United States about 150,000 state, county and local road officials, and that it was necessary to correspond with most of these in order to secure the desired information. In many cases it was necessary to write a number of individual letters to township and other local road officials before the information could be secured.

Every possible effort has been made to verify the accuracy of the figures given in the tables. When there was any doubt as to the correctness of the figures given, they were returned for correction or approval to the person from whom they were received, or to some other person qualified to give correct information. Upon the completion of the tabulations for the various states, they were submitted to the heads of the state highway departments or geological surveys, or to some well-informed person in the state for correction and approval.

The total mileage statistics are based mainly on approximations or estimates from the various civil subdivisions of the United States, as there are very few states or counties where the roads have been actually surveyed and measured, and it will be impossible to secure accurate data in regard to total mileage until this has been done. The statistics in regard to the mileage of improved roads are based more nearly on facts than on estimates, although in many cases the mileage of improved roads was estimated.

It is quite possible, therefore, that, in spite of the precautions which have been taken, some errors have crept in. The total mileage, as well as the mileage of improved roads, may be in some instances overestimated, and in others underestimated. In view of these facts, the Office cannot vouch for the absolute accuracy of all of the figures given in the tables, but it is believed that, taken as a whole, they can be accepted as a fairly accurate record on which to base the progress of road building in the various states during the five-year period treated.

MILEAGE OF ROADS—At the close of 1909 there were 2,199,645 mi. of public roads in the United States, which exceeds the mileage reported for 1904 by 48,266 mi. Mileage statistics are not included for Alaska, Porto Rico, Hawaii, the Philippines, or Guam. The mileage of roads given in the tables does not include the streets or boulevards in incorporated cities or villages.

Of the total mileage of public roads in the United States at the close of 1909, 102,870 mi. were surfaced with gravel, 59,237 mi. with stone, and 28,372 with other materials, which makes a total of 190,479 mi. of improved roads.

By comparing these figures with those collected for 1904, it will be seen that the total mileage of gravel roads reported has decreased by 7035 mi. This is due principally to the fact that in 1904 no information was collected in regard to sand-clay roads, except from the southeastern states, and it is quite probable that a number of the roads which were reported as gravel roads in 1904 were reported in 1909 as sand-clay roads. This decrepancy is also partly accounted for by reason of a reclassification of the roads in several of the states, by which many of the poorly built and poorly maintained gravel roads have been eliminated from the improved road class. An effort was made in this investigation to exclude all natural gravel roads from the improved class unless they were well graded and drained, but many of these were included in the 1904 statistics.

The total mileage of stone roads has increased from 36,818 in 1904 to 59,237 in 1909. The mileage of roads surfaced with other materials, including sand-clay, shells, bituminous-macadam, brick, etc., has increased from 6807 mi. in 1904 to 28,372 mi. in 1909.

Indiana still leads all other states in total mileage of improved roads with 24,956 mi.; Ohio still occupies the second place with 24,106 mi.; New York is third with 12,787 mi.; Wisconsin fourth with 10,167 mi.; Kentucky fifth with 10,114.95 mi.; Illinois sixth with 8914 mi.; California seventh with 8588 mi., and Massachusetts eighth with 8463 mi.

The greatest progress in road improvement has been made in the state of New York, which has increased its mileage of improved roads from 5876 in 1904 to 12,787 in 1909 (6911 mi.), due partly to the fact that New York has been spending about $5,000,000 a year from a $50,000,000 state bond issue on trunk-line highways, in addition to the regular annual expenditures from local revenues of about $5,000,000.

The notable increases in the total mileage of improved roads for the five-year period, 1904-1909, are shown as follows: Georgia from 1634 to 5978 (4344 mi.); Washington from 1976 to 4520 (2544 mi.); Missouri from 2733 to 4755 (2022 mi.); South Carolina from 1878 to 3534 (1656 mi.); Alabama from 1720 to 3264 (1544 mi.); Pennsylvania from 2160 to 3364 (1204 mi.); Tennessee from 4285 to 5353 (1068 mi.); New Jersey from 2422 to 3377 (955 mi.); Florida from 885 to 1752 (867 mi.), and Maryland from 1570 to 2142 (572 mi.).

A decrease in improved roads is reported from California, Michigan, Minnesota and Wisconsin. This decrease may be explained as follows: The practice of improving the earth roads by the use of oil in California has been, to a large extent, discontinued, and this has had the effect of cutting down the mileage of that class of roads considerably and so of reducing the total mileage of improved roads. In Michigan and Minnesota the roads have been reclassified by the state highway departments and the mileage of roads which come under the improved class has been reduced. In Wisconsin the mileage of both stone and gravel roads is a little less than was reported in 1904, owing probably to a more careful classification of the roads than it was possible to make at that time. A reclassification of the roads is also responsible for the decrease in gravel roads in Connecticut, Indiana, Massachusetts, Ohio, Oregon, Utah and Virginia.

In no other class of improved roads has the mileage increased so rapidly during the five-year period as in the case of sand-clay roads. The sand-clay construction consists of mixing sand and clay together in such a way as to produce a road which does not become muddy, and which remains comparatively firm during wet or dry weather. This method of construction is confined principally to the southeastern states, although it is now being used to some extent in the Gulf Coast and middle western states.

The mileage of sand-clay roads has increased from 2979 in 1904 to 24,601 in 1909. Alabama has increased her mileage of sand-clay roads from 12 in 1904 to 1107 in 1909; Georgia from 513 to 4326 during the same period, and South Carolina from 1575 to 3218 in the same length of time. A large mileage of sand-clay roads is shown for Michigan, Washington and Wisconsin, but it is believed that these are not all new roads, but simply roads which were reported as gravel roads in 1904.

PERCENTAGE OF ROADS IMPROVED—It will be seen from Table I that, at the close of 1909, 8.66% of the roads in the United States were improved, representing a gain in the total road mileage improved for the five-year period, 1904-1909, of 1.52% or, in other words, the percentage of improved roads has increased during this period from 7.14 to 8.66%.

Rhode Island occupies the first place in the percentage of roads improved, having, as it does, 49.14%; Massachusetts comes next with 49%; and then follow Indiana, 36.7; Ohio, 27.13; Connecticut, 24.08; New Jersey, 22.76; Kentucky, 18.82; Vermont, 18.40; California, 17.87; Wisconsin, 16.64; New York, 16.13; Washington, 13.19; Maryland, 12.77; Utah, 12.23; Tennessee, 11.66; South Carolina, 11.02, Maine, 10.59, and Michigan, 10.01 per cent.

The following states have between 5 and 10% of the roads improved: Alabama, Delaware, Florida, Georgia, Illinois, Minnesota, New Hampshire and Oregon. There are 22 states which have less than 5% of the roads improved.

COST OF ROAD BUILDING—The cost of road building depends upon a number of factors, the most important of which are the cost of grading, the value of labor and teams, the availability and kinds of materials, the method of construction, the cost of bridges and culverts, the character of the soil and the traffic, the method of supervision and, to a certain extent, the climatic conditions. There are very few localities in the United States where all these factors are exactly alike, and consequently here are but few places where the cost of road building would be the same, even though the same type of construction be employed. Comparisons of the average cost of roads in two localities are of little value, therefore, unless all the conditions are taken into account.

In many parts of the United States the land is so level that no grading is necessary, except to prepare the foundation to receive the materials and to provide suitable ditches to dispose of surface drainage; but in other sections the cost of grading and the cost of bridges, culverts and retaining walls often amounts to more than the cost of surfacing.

In the southern states the cost of labor for road work ranges from 75c. to $1.25 per day, while the cost of double teams with driver ranges from $2.50 to $4 per day. In the North and West, however, laborers receive from $1.50 to $2 per day for this class of work, while the prices paid for double teams with drivers range from $3.50 to $5 per day'

TABLE I. MILEAGE OF PUBLIC ROADS IN UNITED STATES, 1904 AND 1909

	1904	1909
Total mileage	2,151,379	2,199,645
Mileage of improved roads:		
Stone	36,818	59,237
Gravel	109,905	102,870
Other materials	6,807	28,372
Total	153,536	190,479
Percentage of all roads improved	7.14	8.66
Mileage of sand-clay roads	2,979	24,601

This partly accounts for the fact that roads of the same type frequently cost more in the North and West than in the southern states, where the cost of labor is generally low.

The distance that road materials have to be hauled determines, to a large extent, the cost of the work. In many parts of the country material is so plentiful that the average haul does not exceed 1 or 2 miles, while in other parts of the country materials have to be transported long distances by rail or water and then hauled several miles by country road. This factor alone very frequently affects the cost to such an extent that a macadam or gravel road will cost considerably more in one part of a county than the same kind of a road will cost in another part of the same county.

In rolling and mountainous sections of the country the cost of bridges and culverts frequently amounts to as much as the cost of surfacing, whereas in level regions and especially where the rainfall is light this item of expense is very small.

At times the temperature falls as low as from 40° to 50° F. below zero in certain parts of the northern states, while there are many places on the Pacific Coast and in the southern states where the temperature rarely falls below the freezing point. It is obvious, therefore, that heavier and more expensive types of road are required in regions where the ground freezes several feet below the surface than in those sections where the ground is seldom frozen. The annual rainfall ranges all the way from 8 to 10 in. in Arizona, California, Colorado, Nevada and northwest Texas to from 50 to 60 in. in parts of Florida, Alabama, Georgia, Mississippi, Louisiana, Tennessee, Arkansas and southeast Texas. The rainfall, as much as any other factor, affects the condition of the road and, while good earth and gravel roads often give entire satisfaction where the rainfall is light, a more durable and expensive type of road must be built where the rainfall is heavier. If the rainfall is light, however, and the traffic is heavy, as is the case in many of the arid regions of the West, special treatment for laying the dust and preserving the surface with oil and other preparations sometimes becomes necessary.

The condition of the soil also affects the cost of road building. For instance, on sandy loams and gravelly soils 4-in. macadam roads are being successfully built and maintained in many parts of the country. In other localities it has been found necessary to macadamize to a depth of from 8 to 10 in. on certain types of clay soils and fine silt loams, while sometimes the Telford method of construction, or the V-shaped drain foundation must be resorted to in order to obtain a solid and durable road. One of the most important factors affecting the cost is that of the traffic. A road which would be satisfactory for light carriage traffic would not always be suitable for heavy wagon traffic, and, on the other hand, a road which would be satisfactory for heavy, horse-drawn, steel-tired traffic would not be, as a general rule, suitable for fast automobile traffic. The character and cost of construction are, therefore, largely determined by the traffic to which the road is subjected.

Table II presents a summary of the information secured from the various states in regard to the cost of four of the standard types of construction; i.e., sand-clay, gravel, macadam and bituminous macadam.

It was impossible to obtain cost data from Illinois, as all information contained in this bulletin relating to that state was secured from the state highway department, which was unable to furnish any cost data, and it was too late, when this fact became known, to collect information from the various counties and townships. The cost data obtained from Arizona, Idaho, Iowa, Nevada, New Mexico, North Dakota, South Dakota and Wyoming were so meager as to be of little value, and are, therefore, not included.

It will be seen from the table that the cost of gravel roads is greater in Maine, New Hampshire and Connecticut than in Indiana, Ohio and Minnesota. In the states last named the statute labor tax is still used, and many of the gravel roads are built by farmers in working out their tax, while in the states first named the standard of construction is much higher and all road taxes are paid in cash.

It is believed that the figures given in the summary represent approximately the average cost of road building in the respective states, as they are based upon reports received in regard to the actual cost of road building. Some of the county and township reports are based on one section of road only, but most of them are based on the average cost of construction in the county or township from which the report was received.

In sending out queries in regard to the cost of road building, correspondents were requested to give the cost per mile or per square yard. It is obvious that this information would be more useful, especially to engineers, if the returns were expressed in cost per square yard instead of cost per mile; but, as most of the correspondents stated the cost per mile, it is so given in the summary.

The cost of large bridges and extraordinary construction, such as retaining walls, etc., is not included, except in a few instances, but the cost of small bridges and all ordinary construction, including surface drainage, is included.

The average cost of the four types of construction referred to in the summary, table II, is as follows: The average cost of sand-clay roads for the 17 states from which reports were received is $723 per mi., the average width of surface treated 17 ft., and the average depth of the material 9 in. It will be noticed that there are quite a number of states for which no report is given. This is due to the fact that the sand-clay method is adapted only to certain portions of the country where the soil and climatic conditions are favorable to its construction. This method of road building seems to be peculiarly adapted to the states embraced in the Atlantic Coastal Plain, although it has been used to some extent in the middle western states. In the middle west, however, this method is still in the experimental stage.

The average cost of gravel roads for the 31 states from which reports were received is $2047 per mi. The average width of gravel surface is 13 ft. and the average depth of the material 7 in.

The average cost of macadam roads for the 34 states from which reports were received is $4989 per mi. The average width of macadam surface is 13 ft. and the average depth of the material 6 in.

In view of the fact that the mileage of poorly built macadam, gravel and sand-clay roads exceeds the mileage of properly constructed roads of the same types, the above figures should not be used as a basis of comparison in communities where the roads are being built according to the latest and most approved methods, for it is safe to say that in such places the cost will considerably exceed the average given above.

The average cost of bituminous-macadam roads for the 10 states from which reports were received is $10,348 per mi. for roads surfaced to a width of 15 ft. and to a depth of 6 in. The information received in regard to bituminous construction, however, is rather meager, and it is believed that it does not represent the average cost of country roads, as do the figures in regard to other methods of construction. The reason for this is that this method of construction is new and to some extent experimental. Furthermore, bituminous-macadam roads have, up to the present time, been built only in the neighborhood of the larger cities, where the cost of labor is comparatively high, and where the roads would naturally be surfaced to a greater width than the roads farther out in the country. It is believed, therefore, that the cost is greater than will be the case when this method of construction becomes more general and when this type of road building becomes standardized.

TABLE II. AVERAGE COST PER MILE OF IMPROVED ROADS IN VARIOUS STATES IN 1909

State	Sand-clay, dollars	Gravel, dollars	Macadam, dollars	Bituminous, dollars
Alabama	680	1,483	2,525	[1]13,250
Arkansas	.....	940	3,250	.....
California	412	1,375	5,375	8,575
Colorado	.....	1,475	.....	.....
Connecticut	.....	5,412	[2]8,220	.....
Delaware	[3]	[4]	6,850	10,120
Florida[5]	829	3,900	[6]3,112	.....
Georgia	387	1,250	2,275	.....
Indiana	.....	1,887	2,657	.....
Kansas	785	.....	4,070	.....
Kentucky	.....	1,011	2,158	.....
Louisiana[7]	654	2,100	.....	.....
Maine	.....	3,687	9,022	[8]19,681
Maryland[9]	1,775	1,000	8,192	.....
Massachusetts	.....	.....	7,451	[10]9,714
Michigan	.....	1,843	4,346	.....
Minnesota	766	946	3,280	.....
Mississippi	.....	2,058	5,135	.....
Missouri	.....	1,023	3,388	.....
Montana	[11]	[1] 800	.....	.....
Nebraska	933	.....	[1]6,000	[1]8,448
New Hampshire	.....	2,352	5,016	.....
New Jersey	.....	4,317	8,746	9,930
New York	.....	5,950	9,496	.....
North Carolina	506	1,006	4,020	.....
Ohio	[12]	1,909	4,580	7,766
Oklahoma	389	.....	3,750	.....
Oregon	.....	1,940	3,491	.....
Pennsylvania	.....	1,575	9,164	10,000
Rhode Island	.....	.....	[13]	[14]
South Carolina	415	1,133	3,252	.....
Tennessee	1,050	1,697	2,727	.....
Texas[15]	593	1,708	2,160	[1]6,000
Utah	718	2,188	5,000	.....
Vermont	.....	[16]1,600	.....	.....
Virginia	607	2,200	4,920	.....
Washington	.....	2,600	7,600	.....
West Va	.....	.....	5,414	[17]
Wisconsin	800	1,135	2,978	.....
Average	723	2,047	4,989	10,348

[1] For one section of road only.
[2] Average cost of telford macadam, $11,323.47; telford gravel, $7,659.71 per mi.
[3] $0.15 per sq.yd.
[4] $0.25 per sq.yd.
[5] Average cost of shell roads, $3,186.
[6] Marl and coral, sometimes referred to as cocina.
[7] Average cost of shell roads, $3,000.
[8] Some of these roads are 40 ft. in width.
[9] Average cost of shell roads, $2,984 per mi.
[10] Average cost of three sand and oil roads $4,718.66 per mile.
[11] $0.23 per square yard.
[12] Average cost of brick roads, $12,381 per mi.
[13] 80 cents per sq.yd.
[14] $1.25 per sq.yd.
[15] Average cost of shell roads, $3,083 per mi.
[16] Telford gravel roads, $2,500 per mile.
[17] Average cost of brick roads, $14,500 per mi.

An Explosion of Gasoline used by mistake in place of kerosene for starting a fire caused the death of four persons near Ariola, Mo., Jan. 21.

A Boiler Explosion at a Calamine Mine, near Joplin, Mo., Jan. 15, caused the death of three workmen and the serious injury of a fourth. The boiler house was wrecked.

A Grain Elevator Explosion at Chicago, Jan. 25, wrecked the elevator of the Acme Milling Co., at North 45th and Bloomingdale Aves. The fire which followed the explosion completed the destruction of the building. The building was 120 ft. long, 50 ft. wide and 100 ft. high. An explosion of grain dust, which destroyed a grain elevator at Richford, Vt., was noted in Engineering News in the issue of Oct. 22, 1908, p. 444. Other grain-dust and elevator explosions in the past few years include that which destroyed the American Milling Co.'s stock food factory at Linden, Ind., Nov. 14, 1908, and the one at Buffalo, N. Y., noted in Engineering News, Jan. 6, 1910, which wrecked the plant of the Buffalo Cereal Co.

A Locomotive Boiler Exploded while pulling New York Central & Hudson River R.R. train No. 49, on Jan. 26, near the western limit of Oneida, N. Y. The engineer was killed and the fireman seriously injured. Only one car left the rails. Reports state that the temperature at the time of the accident was between 15° and 20° below zero, and the explosion is ascribed to the freezing of the feed-water line between the locomotive and the tender.

The Boiler of a River Steamer exploded Jan. 19, on the Willamette River, near Kalama, Wash. The captain, first mate and fireman were killed and the vessel, the "Sarah Dixon," owned by the Shaver Transportation Co., was sunk. All on board except those killed by the explosion got ashore in small boats.

A Cartridge Factory Explosion at Perth Amboy, N. J., Jan. 24, partially wrecked one of the buildings of the U. S. Cartridge Co., and caused the death of one employee, a girl who was operating a machine for feeding powder into cartridge shells. Reports state that about 100 of the girls employed at the factory have refused to return to work until safety devices of some sort have been installed.

Blame for the Wreck on the Illinois Central R.R., at Kindmundy, Ill., Jan. 22, in which James T. Harahan, former president of that road, was killed, has been placed upon three trainmen. The conductor and the flagman of train No. 25, the train ahead, are held to have been negligent in making no use of fusees to warn train No. 3, which they knew to be close behind. The engineer of train No. 3 is held to be blameworthy for not noticing sooner his proximity to the train ahead. It was found that the tail lights of a train at Kinmundy were visible from a point two miles north and at all intermediate points, under weather conditions similar to those prevailing at the time of the accident. It appears from press reports that no automatic block signals are in use on that part of the Illinois Central where the collision occurred, and that a time-interval system of train spacing was employed.

The report placing the blame on the three trainmen was made by a board of inquiry, whose membership included officials of the Illinois Central R.R., J. B. Berry, Chief Engineer of the Chicago, Rock Island & Pacific Ry., and Dean W. F. M. Goss, of the University of Illinois.

A Concrete Dam in northern New York recently developed two very considerable leaks. The dam is owned by the International Paper Co., and is located on the Saranac River at Kent's Falls. As the dam is now covered with several feet of ice, it is impossible to make an accurate statement as to the cause of these leaks. Engineers who have visited the dam believe that the extremely cold weather of the past month caused contraction of the dam and the stresses were probably increased by ice pressure. The water level back of the dam has been lowered and a thorough inspection will be made when warmer weather comes.

The Hudson River Tunnel at Storm King for the Catskill Aqueduct, the deepest water-supply tunnel in the world, was "holed through," on Jan. 30, in the presence of Mayor Wm. J. Gaynor, of New York City, the Commissioners and principal engineers of the Board of Water Supply and a party of prominent engineers, contractors and city officials. This tunnel forms a part of the long aqueduct from the Ashokan Reservoir in the Catskill Mountains to New York City, and has been given much study by the engineers of the work from the time the earliest plans were made, on account of the great depth necessary in order to have the tunnel in solid rock. The preliminary work on this tunnel, including the diamond-drill explorations and the sinking of shafts on either shore were described by Mr. Alfred D. Flinn, Department Engineer of the Board of Water Supply in Engineering News of Mar. 23, 1911.

A contract for driving the tunnel between the shafts was let last spring to the T. A. Gillespie Co., and the work has been pushed with great rapidity since that time. The final meeting of the advance headings was made the occasion by the contractors to invite a party of nearly a hundred engineers, city officials and others, who were taken from New York to the tunnel site on a special train. On arrival at the tunnel the party was lowered to the bottom of the east shaft, where Mayor Gaynor closed a switch firing the final blast at the junction of the headings. The party then walked through the under-river tunnel to this point, where brief addresses were made by the Mayor and by Hon. Chas. Strauss, Chairman of the Board of Water Supply, proposing toasts to the engineers and contractors, which were drunk at tables which had been set in the tunnel.

The tunnel, which is nearly 1200 ft. below the surface of the river, is remarkably free from water, and the rock through which it is driven is very solid and free from seams. Less than a hundred feet of bench remains to be removed to complete the tunnel excavation, and the lining of the tunnel with concrete will then be pushed with all speed. The successful driving of the tunnel is of great importance to New York City as upon its completion depends the bringing down of water from the Catskills to replenish the Croton supply, now dangerously overtaxed. That it should have been driven with so little trouble from water is very gratifying to the Board of Engineers which originally planned the Catskill supply, and to the consulting geologists who approved this site for the Hudson River crossing.

Personals

Mr. J. R. Gilhula has resigned as Superintendent of the Illinois Traction System, at Springfield, Ill.

Mr. H. E. Phelps has been appointed City Engineer of Boulder, Colo., succeeding Mr. Fred R. Dungan, who has resigned.

Mr. Andrew Ross, Division Superintendent of the New York, New Haven & Hartford R.R., at Taunton, Mass., has resigned to become Superintendent of the New York division of the Lehigh Valley R.R.

Messrs. S. A. Staege, of Watertown, N. Y., and R. H. Bennett, of New York City, have formed a partnership under the firm name of Staege & Bennett, Consulting, Civil, Steam and Electrical Engineers, Watertown, N. Y.

Mr. Walter L. Drager, Jun. Am. Soc. C. E., formerly Assistant to Mr. O. P. Thomas, Consulting Engineer of Johnstown, Penn., has been appointed Assistant Engineer of the Department of Public Works of Schenectady, N. Y.

Mr. Charles F. Breitzke, Jun. Am. Soc. C. E., has resigned as Assistant Engineer with the Board of Water Supply of the City of New York, to become associated with Johnson & Fuller, Consulting Engineers, 150 Nassau St., New York City.

Mr. W. O'D. Rockwell, formerly Assistant City Engineer, has been appointed City Engineer of Savannah, Ga., to succeed Mr. J. W. Howard, resigned. To succeed Mr. Rockwell the city council has selected Mr. Roy M. Bailey, who has been a member of the City Engineers' staff for eight years.

Mr. E. L. Brown, formerly General Superintendent of the Western division of the Great Northern Ry., at Spokane, Wash., has been elected Vice-President and General Manager of the Denver & Rio Grande R.R. Mr. Brown was born in Iowa, in 1864, and entered the railway service as a messenger boy with the Chicago, Rock Island & Pacific Ry. when 11 years old.

Mr. John A. Fox, M. Am. Soc. C. E., for a number of years Special Director of the National Rivers and Harbors Congress, has been appointed Commissioner at Large of the Panama California Exposition to be held at San Diego, Calif., in 1915. Mr. Fox is a native of Louisiana and a graduate of Tulane University of that state. For a number of years he was an engineer engaged in levee work on the lower Mississippi River.

Mr. George J. Henry, M. Am. Soc. M. E., Chief Engineer of the Pelton Water Wheel Co., San Francisco, Calif., has resigned to enter private practice as a hydraulic and mechanical engineer, with offices in the Rialto Bldg., San Francisco. Mr. Henry has been with the Pelton Water Wheel Co. for 18 years, 10 years of which he has been Chief Engineer, and is the inventor and patentee of numerous improvements in hydraulic machinery.

Mr. Baird Snyder, Jr., M. Am. Inst. M. E., has resigned as Superintendent of Mines of the Lehigh Coal & Navigation Co., at Lansford, Penn. The office of Superintendent of Mines has been abolished and the duties hitherto connected with that office will be performed by Mr. Edwin Ludlow, M. Am. Inst. M. E., formerly General Manager of the Mexican Coal & Coke Co., Las Esperanzas, Mexico, who has been appointed Second Vice-President.